DEPARTMENT OF THE INTERIOR,

CENSUS OFFICE.

FRANCIS A. WALKER, Superintendent,
Appointed April 1, 1879; resigned November 3, 1881.

CHAS. W. SEATON, Superintendent,
Appointed November 4, 1881. Office of Superintendent abolished March 3, 1885.

REPORT

ON THE

PRODUCTION, TECHNOLOGY, AND USES

OF

PETROLEUM AND ITS PRODUCTS,

BY

S. F. PECKHAM,
SPECIAL AGENT.

WASHINGTON:
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PROVIDENCE, R. I., *October* 6, 1882.

HON. C. W. SEATON,
Superintendent of Census.

SIR: I herewith submit my report as special agent for collecting the statistics of the mining and manufacture of petroleum for the year ending May 31, 1880.

The statistics of mining were gathered, as stated in the chapter devoted to their consideration, by personal interviews with those parties who handled the oil, and from a careful examination of the localities producing it.

The statistics of manufacture were obtained by means of a printed schedule of questions, which was addressed to each firm or corporation engaged in manufacturing petroleum. The answers to the questions contained in these schedules were consolidated into the separate items as given in the report.

An examination of the literature of petroleum revealed a very large number of articles and references, some of which were of even classical antiquity, but the larger number of which had been published within the present century. Very few bound volumes have been devoted to the general consideration of the subject; and none of these, while each valuable as presenting some of its particular aspects, were to be considered as embracing the results of a comprehensive research with reference to all of its varied details. It was therefore thought advisable to make this report an authority upon the subject of which it treats, as embodying the results of a careful examination of the entire literature of petroleum, as well as a careful use of all other available sources of information. The three aspects of the subject—the natural history, technology, and uses of petroleum and its compounds—were each considered under its several appropriate divisions, these forming the subjects of separate chapters. Each of these several chapters, in turn, represents a special research and constitutes a separate independent essay. This arrangement, it is hoped, will facilitate the use of the report for all the varied purposes for which it may be sought. Any further details will, I think, be readily apparent upon an inspection of the work itself.

I wish herewith to express my great obligations to all of those from whom I have solicited assistance in the collection of the statistical material for this report. Without the cordial co-operation of the officers of the great corporations which produce, distribute, and manufacture petroleum, together with a very large number of private individuals, my labors would have been in vain; and I make this statement, appreciating the fact that this assistance in a great number of instances involved a large amount of perplexing labor, gratuitously rendered from an appreciative estimate of the work upon which the Census Office has been engaged. When hundreds of persons throughout the country, engaged in the production, transportation, and manufacture of petroleum, uniformly rendered all of the assistance in their power, it is both difficult and unfair to make distinctions. I had rather repeat what I have said privately: that the patience, forbearance, and uniform courtesy with which I have been met by all parties representing the petroleum interest has been extremely gratifying.

In securing information other than statistical I am under great obligations to Professor J. P. Lesley and his assistants, of the second geological survey of Pennsylvania, particularly Mr. J. F. Carll, of Pleasantville, Pennsylvania. Beside the obligation involved in extensive quotation from Mr. Carll's published reports, his personal assistance in the way of introduction to both persons and places throughout the oil-producing section proved invaluable. I feel that whatever value the report may possess in reference to the geology of West Virginia is due to Mr. F. W. Minshall, of Parkersburg, West Virginia, who, in addition to furnishing the geological sections, rendered me further assistance in introductions and information involving a long correspondence.

In collecting the statistics of foreign localities I am under special obligations to Mr. Boverton Redwood, of London, England; Mr. E. W. Binney, of Manchester, England; Dr. Ferd. Roemer, of Breslau, Silesia; M. P. E. De Ferrari, of Genoa, Italy; Rev. J. N. Cushing, of Prome, Burmah; Dr. James Harris, of Yokohama, Japan; and William Brough, esq., of Franklin, Pennsylvania. To all of these gentlemen I am indebted for the careful collection of statistics and private correspondence.

The extent and value of my researches upon the literature of petroleum have been largely due to the assistance that I have received from the librarians of Brown University, Harvard College, the Boston Public Library, and the American Philosophical Society, and especially to Professor J. D. Whitney, whose valuable private library was generously placed at my disposal. With the exception of a few East Indian publications, these libraries enabled me to verify all of the references with which I came in contact.

Mr. J. C. Welch, of New York, whose statistics and reports bear such a deservedly high reputation for reliability, has rendered me much varied and valuable assistance not otherwise available.

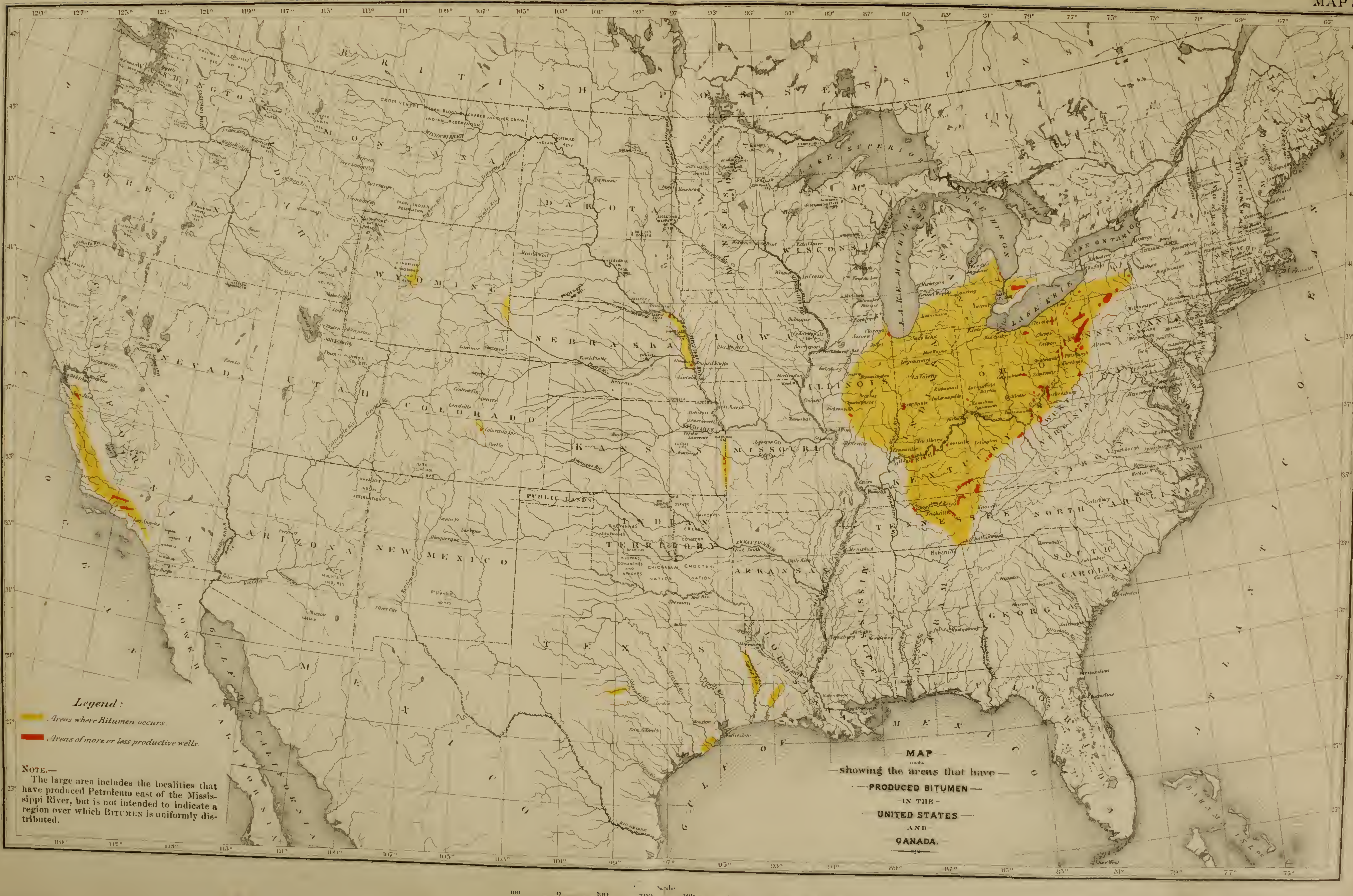
I wish further to express my obligations to Miss Laura Linton, who has assisted me in the preparation of this report, and to whose varied accomplishments I am indebted for many of the translations and illustrations that add completeness and embellishment to the work; also to the officials of the Census Office, to whose uniform courtesy I am indebted for assistance in a somewhat arduous and perplexing undertaking.

Very respectfully,

S. F. PECKHAM,

Special Agent.

MAP II.


Legend:
Areas where Bitumen occurs.
Areas of more or less productive wells.
NOTE.—
The large area includes the localities that have produced Petroleum east of the Mississippi River, but is not intended to indicate a region over which BITUMEN is uniformly distributed.
MAP
showing the areas that have
PRODUCED BITUMEN
IN THE
UNITED STATES
AND
CANADA.
Scale
100 0 100 200 300 400 500 600 Miles

PART I.

THE NATURAL HISTORY OF PETROLEUM,

TOGETHER WITH

A DESCRIPTION OF THE METHODS EMPLOYED IN THE PRODUCTION, TRANSPORTATION, AND SALE OF PETROLEUM IN THE UNITED STATES,

AND

STATISTICS OF THE PRODUCTION OF PETROLEUM IN THE UNITED STATES AND FOREIGN COUNTRIES

DURING THE

YEAR ENDING MAY 31, 1880.

PART I.

CHAPTER I.—HISTORY OF THE DISCOVERY OF PETROLEUM AND THE DEVELOPMENT OF THE PETROLEUM INDUSTRY.

SECTION 1.—HISTORICAL NOTICE OF BITUMEN PRIOR TO THE YEAR 1800.

The word petroleum means rock-oil, and in its present form it is adopted into English from the Latin. Its equivalents in German are *Erdöl* (earth-oil) and *Steinöl* (stone-oil); in French and the other languages of southern Europe the word is *Pétrole*—equivalent to petroleum. Within a few years the Germans have also used the word "petroleum".

Petroleum is one of the forms of bitumen, and cannot be discussed historically except in connection with the other forms. These are:

Solid: Asphaltum.—German, *Asphalt*, *Erdharz*, or *Erdpech;* French, *Asphalte.*

Semi-fluid: Maltha.—French, *Goudron minéral;* Spanish, *Brea.*

Fluid: Petroleum; Volatile: Naphtha.—German, *Naphta*, from Persian *Nafta* or *Neft gil.*

Gaseous: Natural gas.—Of burning springs.

The word *Nafta* appears to have been used by the Persians, and its equivalent, *Naphtha*, has been frequently used in European literature to designate what is now called petroleum, and not the most volatile form of fluid bitumen occurring in nature. Solid bitumen is to be distinguished from coal in the manner of its occurrence, and also by the action of various solvents, especially benzole and carbon disulphide, which dissolve asphaltum, but have no action upon coal.

Bitumen has been known and applied to the uses of mankind from the dawn of history. Its very wide distribution has led to its frequent notice by observers of natural phenomena, and the records of such observations have been as widely extended as the occupation of the earth by civilized man. Herodotus wrote of the springs in the island of Zante as follows:

I have myself seen pitch drawn up out of a lake and from water in Zacynthus; and there are several lakes there; the largest of them is seventy feet every way, and two orgyæ in depth; into this they let down a pole with a myrtle branch fastened to the end, and then draw up pitch adhering to the myrtle; it has the smell of asphalt, but is, in other respects, better than the pitch of Pieria. They pour it into a cistern dug near the lake, and when they have collected a sufficient quantity they pour it off from the cisterns into jars. (*a*)

The springs called Oyun Hit (the fountains of Hit) are celebrated by the Arabs and Persians, the latter calling them *Cheshmeh Kir* (the fountain of pitch). This liquid bitumen they call *Nafta;* and the Turks, to distinguish it from pitch, give it the name of *Hara sakir* (black mastic). Nearly all modern travelers who went to Persia and the Indies by way of the Euphrates before the discovery of the cape of Good Hope speak of this fountain of bitumen. Herodotus mentions that "eight days' journey from Babylon stands another city called Is, on a small river of the same name, which discharges its stream into the Euphrates. Now this river brings down with its water many lumps of bitumen, from whence the bitumen used in the wall of Babylon was brought". (*b*)

The people of the country have a tradition that when the tower of Babel was building they brought the bitumen from hence. At the pits of Kir ab ur Susiana bitumen is still collected in the same manner as related by Herodotus. (*c*) He says:

At Ardericca is a well which produces three different substances, for asphalt, salt, and oil are drawn up from it in the following manner: It is pumped up by means of a swipe, and, instead of a bucket, half a wine skin is attached to it. Having dipped down with this, a man draws it up, and then pours the contents into a reservoir, and, being poured from this into another, it assumes these different forms: the asphalt and the salt immediately become solid, but the oil they collect, and the Persians call it *Rhadinance;* it is black, and emits a strong odor.

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a Herodotus, i, 119, iv, 195; B. S. G. F., xxv, 62; J. S. A., vii, 639. *b Ibid.*, i, 179; J. S. A., vii, 639, 640. *c Ibid.*, vi. 119.

Strabo (*a*) mentions the occurrence of bitumen in the valley of Judea, and describes the commerce carried on in this article by the Arab Nabathenes with the Egyptians for the purpose of embalming; also the manner of its occurrence, rising during or after earthquake shocks to the surface of the Dead sea and forming masses resembling islands. Diodorus, of Sicily, describes the lake Asphaltites and the manner in which the savage inhabitants of the country construct rafts, and continues:

> These barbarians, who have no other kind of commerce, carry their asphalt to Egypt and sell it to those who make a profession of embalming bodies, because, without the mixture of this material with the other aromatics, it would be difficult for them to preserve them for a long time from the corruption to which they are liable. (*b*)

This bitumen, with that from the springs of Hit, on the Euphrates, of which Eratosthenes has given such interesting details, and which served to cement the bricks of Babylon, is also used for coating ships, (*c*) and is still used in our own time for coating boats on the Euphrates. (*d*)

The semi-fluid bitumen was used in the construction of Nineveh and Babylon to cement bricks and slabs of alabaster, and the grand mosaic pavements and beautifully inscribed slabs used in the palaces and temples of these ancient cities, many of which were of enormous size, were fastened in their places with this material. It was also used to render cisterns and silos for the preservation of grain water-tight, and some of these structures of unknown antiquity are still found intact in the ancient cities of Egypt and Mesopotamia. The naphtha is more highly valued than the solid bitumen, the most fluid varieties being used in lamps. The Persians also manufacture dried dung in long sticks, which are dipped in naphtha and burned for lights, and it is also used for cooking and heating; but in order to avoid the unendurable smell a peculiar kind of chimney is carried into each room. Cotton wicks are also used in naphtha to some extent. The white or colorless naphtha, which is most rare, is used by the apothecaries. (*e*)

Aristotle, Strabo, Plutarch, Pliny, and others describe at some length deposits of bitumen occurring in Albania, on the eastern shores of the Adriatic sea, (*f*) and similar notices of petroleum springs and gas wells in China occur in the earliest records of that ancient people. Pliny and Dioscorides described the oil of Agrigentum, which was used in lamps, under the name of "Sicilian oil".

The soft bitumen in the Euphrates valley is that of which we have the earliest mention. (*g*) The word translated *slime* in the English version of Genesis xi, 3, is ἄσφαλτος in the Septuagint and *bitumen* in the Vulgate, and this is what is meant. The great abundance of petroleum at Baku, on the Caspian sea, and the remarkable sight presented by the flaming streams of oil and discharges of gas, have been the subject of many descriptions. The fire temple at Baku has had a special interest in connection with India, not only from its general similarity to that of Jawálamúhki, near Kangra, in the Punjab, (*h*) but also from the circumstance that the Baku temple has for a long time and down to the present day been, like the other, a place of Hindoo pilgrimage. The great conflagrations of oil upon the ground have not been constant, and hence many travelers do not mention them.

Marco Polo describes the great abundance of the discharges of oil at Baku, and says that people came from a vast distance to collect it. (*i*) Baku is described by Kaempfer, who was there in 1684. (*j*) In 1784 it was visited by Forster, on his journey from India to England, who has given an account of the place and of the Hindoo merchants and mendicants residing there.

Between Kaempfer and Forster came Jonas Hanway, who gives a description of Baku, the fire temple, and the Hindoos, and the great quantities of oil obtained at that time, chiefly from certain islands in the Caspian sea. Descriptions are given by other travelers, ancient and modern, of this oil region,(*k*) of the copious discharges of white and black naphtha, the streams of flaming oil on the hillsides, the gas and the fire temple, and the explosive effects of the ignition of the gas mixed with atmospheric air. (*l*)

A tradition is preserved in Plutarch that a Macedonian who had charge of Alexander's baggage is said to have dug on the banks of the Oxus: "There came out, which diffired nothing from natural oile, having the glosse and fatness so like as there could be discovered no differense between them." (*m*)

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a Tome XVI, ch. ii.

b Tome I L, II., cap. xxix.

c Strabo, I, xvi, cxii.

d Lartet, B. S. G. F., xxiv, p. 12.

e Ritter's *Erdkunde*, II, 578.

f Strabo, VI, 763; Pliny, N. H., VII, 13; Josephus, B. I., IV, 8, 4; Tacitus, Hist., V, 6; Mandeville, Rochon, etc. Plutarch: Life of Sylla; Dion Cassius, Rom. Hist. c. XLI; Ælian Variæ Hist., XIII, 16; quoted in B. S. G. F., xxv, 21.

g Herod, I, 179; Philostr. Apoll. Tyan., I, 17; D'Herbelot, Biblioth. *Or. o. v. Hit.*

h G. T. Vigne, *Travels in Cashmir and Little Thibet*, 1842, p. 133.

i Book I, ch. III (vol. I, p. 46, Col. Yule's ed., 1871), note in Marsden's ed.

j Amoenit. Exot., p. 224. Colburn's Nat. Libr., i, 263.

k *Wonders of the East*, by Friar Jordanus, p. 50 (Colonel Yule's note); *Keppel's Journey from India to England*, 1824; *A Journey from London to Persepolis*, by J. Usher, 1865; Morier's *Journey;* Kinneir's *Persia; Some Years' Travels*, by Tho. Herbert, 1638.

l I am indebted for many of the preceding facts and references to an excellent article on "Naphtha" by M. C. Cooke, J. S. A., vii, 638; also, Colonel R. Maclagan, on the "Geographical Distribution of Petroleum and Allied Products", P. B. A. A. S., 1871, 180.

m Sir Thomas North's translation of *Plutarch's Lives*, ed. 1631, p. 702.

The occurrence of petroleum in North America was noticed by the earliest explorers, as the Indians dwelling in the vicinity of the great lakes applied it to several purposes, and thus brought it to the attention of those who went among them; but the earliest mention that has come under my notice is of 1629. A Franciscan missionary, Joseph de la Roche D'Allion, who crossed the Niagara river into what is now the state of New York, wrote a letter, in which he mentions the oil-springs and gives the Indian name of the place, which he explained to mean, "There is plenty there." This letter was published in Sagard's *Histoire du Canada*, 1632, and subsequently in *Le Clerc*.

Peter Kalm published in Swedish about the middle of the last century a book of travels, in which was a map, on which the springs on Oil creek were properly located. This book has been translated into English, and an edition was published in London in 1772.

In the first volume of the *Massachusetts Magazine*, published in 1789, appears the following notice: (*a*)

In the northern part of Pennsylvania is a creek called Oil creek, which empties into the Allegheny river. It issues from a spring, on which floats an oil similar to that called Barbadoes tar, and from which one may gather several gallons in a day. The troops sent to guard the western posts halted at this spring, collected some of the oil, and bathed their joints with it. This gave them great relief from the rheumatism with which they were afflicted. The water, of which the troops drank freely, operated as a gentle purge.

The earliest records of voyages and travels among the Seneca Indians who occupied northwestern Pennsylvania and southwestern New York contain observations respecting the reverence paid the oil-springs of Oil creek and the contiguous valleys by this people, not only using it for medicinal purposes, but also in religious observances.

The French commander of Fort Duquesne in the year 1750 writes as follows to General Montcalm:

I would desire to assure you that this is a most delightful land. Some of the most astonishing natural wonders have been discovered by our people. While descending the Allegheny, fifteen leagues below the mouth of the Conewango and three above the Venango, we were invited by the chief of the Senecas to attend a religious ceremony of his tribe. We landed, and drew up our canoes on a point where a small stream entered the river. The tribe appeared unusually solemn. We marched up the stream about half a league, where the company, a band it appeared, had arrived some days before us. Gigantic hills begirt us on every side. The scene was really sublime. The great chief then recited the conquests and heroism of their ancestors. The surface of the stream was covered with a thick scum, which, upon applying a torch at a given signal, burst into a complete conflagration. At the sight of the flames the Indians gave forth the triumphant shout that made the hills and valleys re-echo again. Here, then, is revived the ancient fire-worship of the East; here, then, are the children of the Sun. (*b*)

In 1765 the English government sent an embassy to the court of Ava, in Burmah. In the journal of that embassy, by Major Michael Symes, may be found a description of the petroleum wells in the neighborhood of Yenangyoung (Earth-oil creek), a small tributary of the Irrawaddy. For an unknown period the whole of Burmah and portions of India have been supplied with illuminating oil from this source, particularly those regions that are reached by the Irrawaddy and its tributaries.

On page 261 of Symes' *Journal* we read:

After passing various lands and villages, we got to Yenangyoung, or Earth-oil creek, about two hours past noon. We were informed that the celebrated wells of petroleum which supply the whole empire and many parts of India with that useful product were five miles to the east of this place. The mouth of the creek was crowded with large boats waiting to receive a lading of oil, and immense pyramids of earthen jars were raised in and around the village, disposed in the same manner as shot and shell are piled in an arsenal. This is inhabited only by potters, who carry on an extensive manufactory and find full employment. The smell of the oil is extremely offensive. We saw several thousand jars filled with it ranged along the bank; some of these were continually breaking, and the contents, mingling with the sand, formed a very filthy consistence.

Late in the last century springs of petroleum were noticed in West Virginia, in Ohio, and in Kentucky, as explorers and settlers began to penetrate the country west of the Alleghany mountains.

Section 2.—HISTORICAL NOTICE OF BITUMEN FROM THE YEAR 1800 TO 1850.

In Europe, early in the present century, chemists examined the bitumen of the Val de Travers. (*c*) The gas springs of Karamania, noticed by Ctesias more than two thousand years before, again attracted attention, (*d*) and the asphalt deposits of Albania, mentioned by Strabo and Pliny, were again described by Pouqueville. (*e*)

In 1811 Dr. Nicholas Nugent visited the West Indies, and on his return to England wrote an account of the famous pitch lake of Trinidad, near the mouth of the river Orinoco. (*f*) He described the wonderful beauty of the tropical island, with its more wonderful lake of solid yet plastic bitumen, on which were pools of water containing fish and islands of verdure thronged with brilliant birds.

From 1820 to 1830 remarkable activity was manifested in the investigation of the nature and occurrence of bituminous substances. The Hon. George Knox read a communication to the Royal Society of Great Britain, in which he noticed the wide distribution of these substances in nature, and the fact that even so-called eruptive rocks

a Am. C., iii, 174.
b Henry's *Early and Later History of Petroleum*, p. 11.
c De Saussure, A. C. N. P. (2), iv, 314, 620, 308.
d Beaufort: *Survey of the Coast of Karamania*, 1820, p. 24.
e *Voyage en Grèce*, 1820, 1, 271; B. S. G. F., xxv, 22.
f T. G. S., (1) 1, 63.

were rarely found entirely destitute of bitumen as an ingredient. This paper attracted much attention. (*a*) In 1824 Reichenbach discovered paraffine in the products of the destructive distillation of wood, (*b*) and in the following year Gay-Lussac analyzed it. (*c*)

In 1826 the British government sent a second embassy to Ava, and in the journal of that embassy the ambassador, Hon. John Crawfurd, again describes the petroleum wells of Rangoon, and furnishes many details respecting the method of their operation and the amount of their product. (*d*)

Boussingault investigated the bitumen of Pechelbronn, on the lower Rhine, and compared its peculiarities with those of bitumens from other localities. His work on these substances became very celebrated, and has been very widely quoted. (*e*) These researches created a lively interest in France, and led to much experimenting upon both solid and liquid bitumens, with a view to ascertaining the purposes to which they might be applied.

During this period the first well was bored in the United States that produced petroleum in any considerable quantity. As the first well bored or drilled for brine was the legitimate precursor of all the petroleum wells in the country, an historical account of it is introduced here, taken from a paper written by Dr. J. P. Hale, of Charleston, West Virginia, for the volume prepared by Professor M. F. Maury, and issued by the State Centennial Board, on the resources and industries of the state. He says:

It was not until 1806 that the brothers, David and Joseph Ruffner, set to work to ascertain the source of the salt water, to procure, if possible, a larger supply and of better quality, and to prepare to manufacture salt on a scale commensurate with the growing wants of the country.

The Salt Lick, or "the Great Buffalo Lick", as it was called, was just at the river's edge, 12 or 14 rods in extent, on the north side, a few hundred yards above the mouth of Campbell's creek, and just in front of what is now known as the "Thoroughfare Gap", through which, from the north, as well as up and down the river, the buffalo, elk, and other ruminating animals made their way in vast numbers to the lick. * * *

In order to reach, if possible, the bottom of the mire and oozy quicksand through which the salt water flowed they (the Ruffner brothers) provided a straight, well-formed, hollow sycamore tree, with 4 feet internal diameter, sawed off square at each end. This is technically called a "gum". This gum was set upright on the spot selected for sinking, the large end down, and held in its perpendicular position by props or braces on the four sides. A platform, upon which two men could stand, was fixed about the top; then a swape was erected, having its fulcrum in a forked post set in the ground close by. A large bucket, made from half of a whisky barrel, was attached to the end of the swape by a rope, and a rope was attached to the end of the pole, to pull down on, to raise the bucket. With one man inside the gum, armed with pick, shovel, and crowbar, two men on the platform on top to empty and return the bucket, and three or four to work the swape, the crew and outfit were complete.

After many unexpected difficulties and delays the gum at last reached what seemed to be rock bottom at 13 feet. Upon cutting it with picks and crowbars, however, it proved to be but a shale or crust about 6 inches thick of conglomerated sand, gravel, and iron. Upon breaking through this crust the water flowed up into the gum more freely than ever, but with less salt.

Discouraged at this result, the Ruffner brothers determined to abandon this gum and sink a well out in the bottom, about 100 yards from the river. This was done, encountering, as before, many difficulties and delays. When they had gotten through 45 feet of alluvial deposit they came to the same bed of sand and gravel upon which they had started at the river. To penetrate this they made a 3½-inch tube of a 20-foot oak log by boring through it with a long-shanked auger. This tube, sharpened and shod with iron at the bottom, was driven down, pile-driver fashion, through the sand to the solid rock. Through this tube they then let down a glass vial with a string, to catch the salt water for testing.

They were again doomed to disappointment. The water, though slightly brackish, was less salt than that at the river. They now decided to return to the gum at the river, and, if possible, put it down to the bed-rock. This they finally succeeded in doing, finding the rock at 16 to 17 feet from the surface.

As the bottom of the gum was square and the surface of the rock uneven, the rush of outside water in the gum was very troublesome. By dint of cutting and trimming from one side and the other, however, they were at last gotten nearly to a joint, after which they resorted to thin wedges, which were driven here and there as they would "do the most good".

By this means the gum was gotten sufficiently tight to be so bailed out as to determine whether the salt water came up through the rock. This turned out to be the case. The quantity welling up through the rock was extremely small, but the strength was greater than any yet gotten, and this was encouraging. They were anxious to follow it down, but how? They could not blast a hole down there under water; but this idea occurred to them: They knew that rock-blasters drilled their powder holes 2 or 3 feet deep, and they concluded they could, with a longer and larger drill, bore a correspondingly deeper and larger hole. They fixed a long iron drill, with a 2½-inch chisel bit of steel, and attached the upper end to a spring pole with a rope. In this way the boring went on slowly and tediously, till on the 1st of November, 1807, at 17 feet in the rock, a cavity or fissure was struck, which gave an increased flow of stronger brine. This gave new encouragement to bore still further; and so, by welding increasing length of shaft to the drill from time to time, the hole was carried down to 28 feet, where a still larger and stronger supply of salt water was gotten.

Having now sufficient salt water to justify it, they decided and commenced to build a salt furnace, but, while building, continued the boring, and on the 15th January, 1808, at 40 feet in the rock and 58 feet from the top of the gum, were rewarded by an ample flow of strong brine for their furnace, and ceased boring.

Now was presented another difficulty: how to get the stronger brine from the bottom of the well, undiluted by the weaker brines and fresh water from above. There was no precedent here; they had to invent, contrive, and construct anew. A metal tube would naturally suggest itself to them; but there were neither metal tubes, nor sheet metal, nor metal workers, save a home-made blacksmith, in all this region, and to bore a wooden tube 40 feet long, and small enough in external diameter to go in the 2½-inch hole, was impracticable. What they did do was to whittle out of two long strips of wood two long half tubes of the proper size, and, fitting the edges carefully together, wrap the whole from end to end with small twine. This, with a bag of wrapping near the lower end, to fit as nearly as practicable, water tight, in the 2½-inch hole, was cautiously pressed down to its place, and found to answer the purpose perfectly, the brine flowed up freely through the tube into the gum, which was now provided with a water-tight floor or bottom to hold it, and from which it was raised by the simple swape and bucket.

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a P. T., 1823; A. C. et P. (2), xxv, 178.
b P. M. (2), i, 402.
c A. C. et P. (2), 1, 78.
d *Journal of an Embassy to the Court of Ava*, 1834.
e *Constitution of Bitumens*, P. J. (2), ix, 487.

Thus was bored and tubed, rigged and worked, the first rock-bored salt-well west of the Alleghanies, if not in the United States. The wonder is not that it required eighteen months or more to prepare, bore, and complete this well for use, but, rather, that it was accomplished at all under the circumstances. In these times, when such a work can be accomplished in as many days as it then required months, it is difficult to appreciate the difficulties, doubts, delays, and general troubles that then beset them. Without preliminary study, previous experience, or training, without precedents in what they undertook, in a newly settled country, without steam-power, machine-shops, skilled mechanics, suitable tools or materials, failure rather than success might reasonably have been predicted. * * *

For interesting facts in this history of the boring of the first well I am indebted to a MS. by the late Dr. Henry Ruffner, and for personal recollections and traditions I am indebted to General Lewis Ruffner, Isaac Ruffner, W. D. Shrewsberry, Colonel B. H. Smith, Colonel L. I. Woodyard, W. C. Brooks, and others, and my own experiences for the last thirty years. * * *

Other important improvements were gradually made in the manner of boring, tubing, and pumping wells, etc. The first progress made in tubing, after Ruffner's compound wood-and-wrapping-twine tube, was made by a tinner who had located in Charleston. * * * He made tin tubes in convenient lengths, and soldered them together as they were put down the well. The refinement of screw joints had not yet come, but followed shortly after, in connection with copper pipes, which soon took the place of tin, and these are recently giving place to iron.

In the manner of bagging the wells, that is, in forming a water-tight joint around the tube to shut off the weaker waters above from the stronger below, a simple arrangement, called a "seed-bag", was fallen upon, which proved very effective, and which has survived to this day, and has been adopted wherever deep boring is done as one of the standard appliances for the purpose for which it is used. This seed-bag is made of buckskin or soft calfskin, sewed up like the sleeve of a coat or leg of a stocking, made 12 to 15 inches long, about the size of the well hole, and open at both ends; this is slipped over the tube and one end securely wrapped over knots placed on the tube to prevent slipping. Some six or eight inches of the bag is then filled with flaxseed, either alone or mixed with powdered gum tragacanth; the other end of the bag is then wrapped like the first, and the tube is ready for the well. When to their place—and they are put down any depth to hundreds of feet—the seed and gum soon swell from the water they absorb, till a close fit and water-tight joint are made. * * *

In 1831 William Morris, or "Billy" Morris, as he was familiarly called, a very ingenious and successful practical well-borer, invented a simple tool, which has done more to render deep boring practicable, simple, and cheap than anything else since the introduction of steam.

This tool has always been called here "slips", but in the oil regions they have given it the name of "jars". It is a long double-link, with jaws that fit closely, but slide loosely up and down. They are made of the best steel, are about 30 inches long, and fitted, top and bottom, with pin and socket joint, respectively. For use they are interposed between the heavy iron sinker, with its cutting chisel-bit below, and the line of auger poles above. Its object is to let the heavy sinker and bit have a clear, quick, cutting fall, unobstructed and unincumbered by the slower motion of the long line of auger poles above. In the case of fast auger or other tools in the well, they are also used to give heavy jars upward or downward, or both, to loosen them. From this use the oil-well people have given them the name of "jars".

Billy Morris never patented his invention, and never asked for nor made a dollar out of it; but as a public benefactor he deserves to rank with the inventors of the sewing-machine, reaping-machine, planing-machine, printing cylinders, cotton-gin, etc. This tool has been adopted into general use wherever deep boring is done, but outside of Kanawha few have heard of Billy Morris, or know where the slips or jars came from. * * *

The Kanawha borings have educated and sent forth a set of skillful well-borers all over the country, who have bored for water for irrigation on the western plains, for artesian wells for city, factory, or private use, for salt water at various places, for oil all over the country, for geological or mineralogical explorations, etc.

Nearly all the Kanawha salt-wells have contained more or less petroleum, and some of the deepest wells a considerable flow. Many persons now think, trusting to their recollections, that some of the wells afforded as much as 25 to 50 barrels per day. This was allowed to flow over from the top of the salt cisterns to the river, where, from its specific gravity, it spread over a large surface, and by its beautiful iridescent hues and not very savory odor could be traced for many miles down the stream. It was from this that the river received the nickname of "Old Greasy", by which it was for a long time familiarly known by Kanawha boatmen and others.

At that time this oil not only had no value, but was considered a great nuisance, and every effort was made to tube it out and get rid of it. It is now the opinion of some competent geologists, as well as of practical oil men, that very deep borings, say 2,500 feet, would penetrate rich oil-bearing strata, and possibly inexhaustible supplies of gas.

In Ohio salt was manufactured at the "Old Scioto salt works", in Jackson county, as early as 1798, from brine obtained from dug wells. In 1808, after the successful boring of the Ruffner well on the Kanawha, bored wells were substituted for dug wells very successfully, and salt-wells were soon in operation in other localities. The valley of the Muskingum from Zanesville to Marietta soon became noted, and the valley of Duck creek, since the center of the Washington county petroleum fields, was first famous for its salt-wells.

The following description is from an article in the *American Journal of Science* (1), xxiv, 63, by Dr. S. P. Hildreth, of Marietta:

Since the first settlement of the regions west of the Appalachian range the hunters and pioneers have been acquainted with this oil. Rising in a hidden and mysterious manner from the bowels of the earth, it soon arrested their attention, and acquired great value in the eyes of these simple sons of the forest. Like some miraculous gift from heaven, it was thought to be a sovereign remedy for nearly all the diseases common to those primeval days, and from its success in rheumatism, burns, coughs, sprains, etc., was justly entitled to all its celebrity. It acquired its name of Seneca oil, that by which it is generally known, from having first been found in the vicinity of Seneca lake, New York. From its being found in limited quantities, and its great and extensive demand, a small vial of it would sell for 40 or 50 cents. It is at this time in general use among the inhabitants of the country for saddle bruises and that complaint called the scratches in horses. It seems to be peculiarly adapted to the flesh of horses, and cures many of their ailments with wonderful certainty and celerity. Flies and other insects have a natural antipathy to its effluvia, and it is used with much effect in preventing the deposit of eggs by the "blowing fly" in the wounds of domestic animals during the summer months. In neighborhoods where it is abundant it is burned in lamps in place of spermaceti oil, affording a brilliant light, but filling the room with its own peculiar odor. By filtering it through charcoal, much of this empyreumatic smell is destroyed and the oil greatly improved in quality and appearance. It is also well adapted to prevent friction in machinery, for, being free of gluten, so common to animal and vegetable oils, it preserves the parts to which it is applied for a long time in free motion; where a heavy vertical shaft runs in a socket, it is preferable to all or any other articles. This oil rises in greater or less abundance in most of the salt-wells of the Kanawha, and, collecting as it rises, in the head on the water, is removed from time to time with a ladle.

* * * * * * * * *

On the Muskingum river the wells afford but little oil, and that only during the time the process of boring is going on; it ceases soon after the wells are completed, and yet all of them abound more or less in gas. A well on Duck creek, about 30 miles north of Marietta, owned by Mr. McKee, furnishes the greatest quantity of any in this region. It was dug in the year 1814, and is 475 feet in depth.

The rocks passed were similar to those on the Muskingum river above the flint stratum, or like those between the flint and salt deposit at McConnellsville. A bed of coal 2 yards in thickness was found at the depth of 100 feet, and gas at 144 feet, or 41 feet above the salt-rock. The hills are sandstone based on lime, 150 or 200 feet in height, with abundant beds of stone-coal near their feet. The oil from this well is discharged periodically at intervals of from two to four days, and from three to six hours duration at each period. Great quantities of gas accompany the discharges of oil, which for the first few years amounted to from 30 to 60 gallons at each eruption. The discharges at this time are less frequent, and diminished in quantity, affording only about a barrel per week, which is worth at the well from 50 to 75 cents a gallon. A few years ago, when the oil was most abundant, a large quantity had been collected in a cistern holding 30 or 40 barrels. At night, some one engaged about the works approached the well-head with a lighted candle. The gas instantly became ignited and communicated the flame to the contents of the cistern, which, giving way, suffered the oil to be discharged down a short declivity into the creek, whose waters pass with a rapid current close to the well. The oil still continued to burn most furiously; and, spreading itself along the surface of the stream for half a mile in extent, shot its flames to the tops of the highest trees, exhibiting the * * * spectacle of a river actually on fire.

It is probable that wells were drilled for salt in the neighborhood of Tarentum, on the Allegheny river, above Pittsburgh, about 1810. These wells were all comparatively shallow, but in many of them small quantities of petroleum often interfered more or less with their successful operation.

Salt-wells were bored along the Big Sandy river and its tributaries across Kentucky and into Tennessee, and in many of them petroleum appeared in sufficient quantity to be troublesome. In 1818 or 1819 a well was bored on the south fork of the Cumberland river, in Wayne county, Kentucky, that produced petroleum in such quantities that it was abandoned for brine and was almost forgotten for more than thirty years. This well has acquired some notoriety under the name of the Beatty well, and is still yielding small quantities of oil. Farther west, in Barren and Cumberland counties, Kentucky, along the Cumberland river and its tributaries, numerous salt-wells were bored, and in many of them petroleum appeared. In 1829 the famous American well was bored near the bed of Little Rennox creek, near Burkesville, Kentucky. The following account of the phenomena attending its completion is to be found in *Niles' Register* (3), xiii, 4:

Some months since, in the act of boring for salt water on the land of Mr. Lemuel Stockton, situated in the county of Cumberland, Kentucky, a vein of pure oil was struck, from which it is almost incredible what quantities of the substance issued. The discharges were by floods, at intervals of from two to five minutes, at each flow vomiting forth many barrels of pure oil. I witnessed myself, on a shaft that stood upright by the aperture in the rock from which it issued, marks of oil 25 or 30 feet perpendicularly above the rock. These floods continued for three or four weeks, when they subsided to a constant stream, affording many thousand gallons per day. This well is between a quarter and a half mile from the bank of the Cumberland river, on a small rill (creek), down which it runs to the Cumberland river. It was traced as far down the Cumberland as Gallatin, in Sumner county, Tennessee, nearly 100 miles. For many miles it covered the whole surface of the river, and its marks are now found on the rocks on each bank. About 2 miles below the point on which it touched the river it was set on fire by a boy, and the effect was grand beyond description. An old gentleman who witnessed it says he has seen several cities on fire, but that he never beheld anything like the flames which rose from the bosom of the Cumberland to touch the very clouds.

Referring to this article and the well, a correspondent of the *Burkesville Courier*, C. L. S. Mathews, esq., under date October 11, 1876, says:

This well, from the long continued yield of oil, is one of the most remarkable wells in America. When first struck, oil flowed from it at the rate of 1,000 barrels per day, and for many years, in fact, until the year 1860, it yielded a plentiful supply of oil. We have been informed by several old citizens, who witnessed the burning of the oil on the surface of the river, that the oil burned down the river about 56 miles, and that for miles all the vegetation and foliage along the river bank was destroyed. Some years after this strike was made several individuals took charge of the well, saved the oil, and put up several hundred thousand bottles, which they sold all through this country and some parts of Europe as the "American Medicinal Oil, Burkesville, Kentucky".

During the decade from 1830 to 1840 the attention of the most distinguished French chemists was directed to the investigation of bitumens. Boussingault continued his general researches, and in 1837 published a classical paper on the subject. (*a*) Virlet d'Oust propounded the first theory regarding the origin of bitumens in 1834, (*b*) and the asphalt of the Dead sea, (*c*) of Pyrmont, (*d*) and near Havana, Cuba, were examined. (*e*) Hess wrote on the products of dry distillation (*f*) and was reviewed by Reichenbach, (*g*) who, with Laurent, (*h*) continued his researches upon paraffine. In 1833 Professor Benjamin Silliman, sr., contributed an article to the *American Journal of Science* (1), xxiii, 97, in which he describes the celebrated oil-spring of the Seneca Indians near Cuba, New York, as follows:

The oil-spring, or fountain, rises in the midst of a marshy ground; it is a muddy and dirty pool of about 18 feet in diameter, and is nearly circular in form. There is no outlet above ground, no stream flowing from it, and it is, of course, a stagnant water, with no other circulation than that which springs from changes of temperature and from the gas and petroleum which are constantly rising through the pool.

We are told that the odor of petroleum is perceived at a distance in approaching the spring. This may not improbably be true in particular states of the wind, but we did not distinguish any peculiar smell until we arrived on the edge of the fountain. Here its

a A. C. et P. (2), lxiv, 141.
b B. S. G. F. (1), iv, 372.
c *Journal des Savants*, 1855, 596.
d Rozet, B. S. G. F. (1), vii, 138.
e Taylor & Clemson, P. M., x, 161.
f *Pog. An.*, xxxvi, 417, xxxvii, 534.
g *Jour. für Ökonom. Chem.*, viii, 445.
h Laurent, A. C. et P. (2), liv, 392, lxiv, 321.

peculiar character becomes very obvious. The water is covered with a thin layer of petroleum or mineral oil, giving it a foul appearance, as if coated with dirty molasses, having a yellowish-brown color. Every part of the water was covered by this film, but it had nowhere the iridescence which I recollect to have observed at Saint Catharine's well, a petroleum fountain near Edinburgh, in Scotland. There the water was pellucid, and the lines produced by the oil were brilliant, giving the whole a beautiful appearance. The difference is, however, easily accounted for. Saint Catharine's well is a lively, flowing fountain, and the quantity of petroleum is only sufficient to cover it partially, while there is nothing to soil the stream; and in the present instance the stagnation of the water, the comparative abundance of the petroleum, and the mixture of leaves and sticks and other productions of a dense forest, preclude any beautiful features. There are, however, upon this water, here and there, spots of what seems to be a purer petroleum, probably recently risen, which is free from mixture, and which has a bright, brownish-yellow appearance, lively and sparkling; and were the fountain covered entirely with this purer production it would be beautiful.

They collect the petroleum by skimming it, like cream from a milk-pan. For this purpose they use a broad, flat board, made thin at one edge like a knife; it is moved flat upon and just under the surface of the water, and is soon covered by a coating of the petroleum, which is so thick and adhesive that it does not fall off, but is removed by scraping the instrument upon the lip of a cup. It has then a very foul appearance, like very dirty tar or molasses, but it is purified by heating and straining it while hot through flannel or other woolen stuff. It is used by the people of the vicinity for sprains and rheumatism and for sores on their horses, it being in both cases rubbed upon the part. It is not monopolized by any one, but is carried away freely by all who care to collect it, and for this purpose the spring is frequently visited. I could not ascertain how much is annually obtained; the quantity must be considerable. It is said to rise more abundantly in hot weather than in cold.

I cannot learn that any considerable part of the large quantities of petroleum used in the eastern states under the name of Seneca oil comes from the spring now described. I am assured that its source is about 100 miles from Pittsburgh, on Oil creek, which empties into the Allegheny river in the township and county of Venango. It exists there in great abundance, and rises in purity to the surface of the water; by dams, inclosing certain parts of the river or creek, it is prevented from flowing away, and it is absorbed by the blankets, from which it is wrung.

The petroleum sold in the eastern states under the name of Seneca oil is of a dark brown color, between that of tar and molasses, and its degree of consistence is not dissimilar, according to the temperature; its odor is strong and too well known to need description.

In an article entitled "Observations on the bituminous coal deposits of the valley of the Ohio" Dr. S. P. Hildreth, in 1836, notices the occurrence of petroleum on the Little Kanawha. (*a*)

The decade from 1840 to 1850 was remarkable for the number of travelers who, in different parts of the world, noticed the occurrence of bitumen, and also for several elaborate researches upon the geological occurrence and chemical constitution of its different varieties. Travelers visited the far east, and even China, (*b*) and gave glowing descriptions of the naphtha springs of Persia, (*c*) the fire-worshipers of Baku, and the fire wells of China. (*d*) The naphtha springs of Persia are nowhere else described in such detail as in Ritter's *Erdkunde*, published in 1841. (*e*) Boussingault (*f*) continued his researches in France, and in our own country, Percival, (*g*) in Connecticut, and Beck, (*h*) in New York, called attention to the fact that bitumen was of frequent occurrence in thin veins traversing the metamorphic and eruptive rocks of Connecticut, New York, and New Jersey. In 1842 E. W. Binney first called attention to the occurrence of petroleum in the Down Holland Moss, which may be said to have been the first step toward the great paraffine oil industry of Scotland. (*i*)

SECTION 3.—THE RISE OF THE PARAFFINE OIL INDUSTRY.

This decade witnessed the rise of the paraffine-oil industry in Europe and the United States. The success of the manufacture of shale oil at Bathgate, Scotland, by E. W. Binney & Co., from so-called Boghead coal, has been more popularly known through Mr. James Young, one of Mr. Binney's associates. The lessening supply of sperm and whale oils, and their consequent advance in price, led to various attempts to invent or discover a cheaper substitute, and as a consequence the oils manufactured at Bathgate were eagerly sought in the market, especially when lamps were formed that would burn them with complete success. Mr. Binney claims to have first called these oils paraffine oils, but those used for illumination have been more widely known as kerosene. (*j*)

In the United States experiments were commenced in the winter of 1850–'51 by Luther and William Atwood near Boston, which resulted in the establishment in 1853 of the United States Chemical Manufacturing Company at Waltham, Massachusetts. This company manufactured from coal-tar an oil called "Coup oil", which was used, mixed with cheap animal and vegetable oils, for lubricating machinery. In 1854 Mr. Joshua Merrill became connected with this company, but in 1855 he left it and became connected with the Downer Kerosene Oil Company of Boston, with which he has remained to the present time. These three gentlemen were the pioneers in the manufacture of paraffine oils in the United States. In 1857 the Downer Kerosene Oil Company commenced the manufacture of hydrocarbon oils from the Albert coal (a kind of asphaltum), obtained from New Brunswick, and they had works in Boston, Massachusetts, and in Portland, Maine. William Atwood had charge of the works in

a A. J. S. (1), xxix, 121.

b Pottinger; W. Robinson; Ainsworth.

c Kinnier: *Persia.*

d Humboldt: *Asie Centrale*, ii, 519; *Cosmos*, 1, 232; Bohn 1, 221.

e *Die Erdkunde von Asien*, vols. vii, viii, ix, x, and xi.

f A. C. et P. (2), lxxiii, 442.

g A. J. S. (3), xvi, 130.

h A. J. S. (1), xlv, 335.

i Papers read before the Manchester (England) Geological Society, 1842–'43.

j Communication from Mr. Binney to S. F. P.

NOTE.—The claims of Selligue as the original inventor of paraffine oils distilled from shale are stated elsewhere. I think the paraffine-oil industry took its rise at this time.

Portland, Joshua Merrill of those in Boston, and Luther Atwood of a large establishment belonging to the New York Kerosene Oil Company near Brooklyn, Long Island. Before these gentlemen left Waltham they had "experimented upon bituminous coals, bituminous shales, asphaltum, and petroleums—petroleums and bitumens from nearly all the known sources, and many different varieties of coals and shales. They succeeded in producing what they regarded at that time as a good lubricating oil from each of those sources". (*a*)

Previous to going to Portland Mr. William Atwood spent about eighteen months on the island of Trinidad attempting to produce crude lubricating oils from the asphalt of the celebrated Pitch lake.

Meantime, parties in New Bedford, Massachusetts, who had been engaged in the manufacture of whale and sperm oils, commenced the manufacture of paraffine oils from the Boghead mineral of Scotland, which they imported for that purpose. The rich cannel coals of West Virginia and Kentucky soon attracted attention, and works for the manufacture of paraffine oils from them were established at Cloverport, Kentucky, and at Newark, Ohio. On the Allegheny river, in Westmoreland county, Pennsylvania, the Lucesco works were the largest in the country in 1859, having a capacity for producing 6,000 gallons of crude oil per diem. At Canfield, Mahoning county, Ohio, was another, and at Cannelton, West Virginia, was another with refining works at Maysville, Kentucky. By 1859 Luther Atwood had introduced his method of downward distillation, in which a tower was filled with 25 tons of coal or Boghead mineral and a fire kindled on the upper surface by means of anthracite coal or pine wood. (*b*) A downward draft was created by a steam-jet in the pipe leading from the base of the tower, and the heated products of combustion, descending through the coal, expelled the volatile materials at the lowest possible temperature.

In a recent letter, Mr. E. W. Binney, of Manchester, England, who, as before stated, was associated with Mr. James Young, at Bathgate, Scotland, tells me that when Mr. Young, in his celebrated patent lawsuit, testified that he obtained paraffine oil from petroleum before he resorted to coal, and it became known on this side of the Atlantic, the American firms licensed under their patent refused to pay any more royalties and went to work manufacturing petroleum. This is doubtless true as a statement of fact, but it conveys a wrong impression. The fact is that an inadequate supply alone prevented the use of petroleum in this country prior to 1859, and really Mr. Young and those on this side of the Atlantic were then in precisely the same situation as regards petroleum; but at the end of 1859 the situation in America became revolutionized, while that in Scotland remained as before.

Section 4.—HISTORICAL NOTICE FROM 1850 TO THE COMPLETION OF DRAKE'S WELL (AUGUST, 1859).

While Mr. Everett was engaged in making oil from cannel coal at Canfield, Ohio, Dr. J. S. Newberry sent him some petroleum from Mecca, Ohio, which was pronounced "as good or better than crude oil from coal". Oil had been gathered along Mill creek, in Erie, Pennsylvania, since 1854, and had been sold to druggists for a dollar a gallon. At Oxbow hill, not far from Union City, Erie county, Pennsylvania, Mr. P. G. Stranahan and his brothers dug out a spring about 1845 from which oil has flowed ever since.

William C. and Charles Hyde were engaged in lumbering on Oil creek, near the present village of Hydetown, from 1845 to 1850. The former, being well acquainted at that time with the oil-springs near Titusville, went to Pittsburgh and inquired of R. Robinson & Co., grocers, for a cheap oil for lighting mills, and got a half-barrel of amber oil, called "rock-oil", which was used in a vessel resembling a tea-kettle, the wick projecting from the nozzle, and burned much better than the green oil of Oil creek. The latter had long been collected from curbed pits, in which the oil arose and floated upon the water. Blankets were spread upon the water, which absorbed the oil, which was then wrung from them. Mr. J. D. Angier contrived a series of pits, one above another, and allowed the water to flow out from beneath the oil, and in this way he obtained what was then considered a large amount—six gallons a day.

From 1845 to 1855 parties were actively engaged in manufacturing salt at Tarentum, on the Allegheny river, above Pittsburgh, among them a Mr. Kier, whose son, Samuel M. Kier, was a druggist in Pittsburgh. Mr. Kier bored a well for brine at Tarentum and obtained oil that looked like brandy with the water, and this was allowed to flow into the canal leading to Pittsburgh. Mr. Samuel M. Kier's wife was sick, as was supposed, with consumption, and her physician prescribed "American oil". It helped her, and her husband was led to compare it with that obtained from his father's well. Concluding, as they possessed the same odor, that they were the same thing, he submitted them to a chemist, who pronounced them identical. Mr. S. M. Kier soon after commenced to bottle American oil for sale, and after a few years, supposed to be about 1855, in company with Mr. McKuen, he first refined petroleum from his father's wells at Tarentum. The oils were treated like the crude oils obtained from coal, and were made into burning oils and heavier oils, that were sold to the woolen factory at Cooperstown for cleansing wool, for which they were found very valuable. This refinery created a demand for crude petroleum, and led people to reflect upon the possibility of procuring it in larger quantity.

While Kier was at work in Pittsburgh, the firm of Brewer & Watson were engaged in a large lumbering and general merchandise business at Titusville, on Oil creek. In the summer of 1854 Dr. F. B. Brewer, whose

a Testimony of William Atwood in case of Merrill *vs.* Youmans.

b Antisell, page 135.

father was at the head of this firm, visited relatives at Hanover, New Hampshire, and carried a bottle of petroleum to Professor Crosby, of Dartmouth College, of which institution the doctor was a graduate, and Mr. A. H. Crosby, a son of the professor, and now a physician in Concord, New Hampshire, became greatly interested in his representations respecting the petroleum and the oil-springs. At this time Mr. George H. Bissell, also a native of Hanover, and a graduate of Dartmouth, was on a visit to his old home, and was induced by the others to join an enterprise for forming a stock company for procuring petroleum on Oil creek. Mr. Bissell was then engaged in the practice of law in New York as a member of the firm of Eveleth & Bissell. After some time spent in negotiation, during which Dr. Crosby had visited Oil creek and advised boring as a means of obtaining the oil in larger quantities, an arrangement was effected with Messrs. Brewer & Watson, under which Messrs. Eveleth & Bissell proceeded to organize a company.

Under date of November 6, 1854, these gentlemen informed Dr. Brewer that they "had forwarded several gallons of the oil to Mr. Atwood, of Boston, an eminent chemist, and his report of the qualities of the oil and the uses to which it may be applied was very favorable. Professor Silliman, of Yale College, is giving it a thorough analysis, and he informs us that, so far as he has yet tested it, he is of opinion that it contains a large proportion of benzole and naphtha, and that it will be found more valuable for purposes of application to the arts than as a medicinal, burning, or lubricating fluid".

The first deed from Brewer, Watson & Co. was dated November 10, 1854, and conveyed to George H. Bissell and Jonathan G. Eveleth, of New York city, 105 acres of land on what was known as the "Watson flats", embracing the island at the junction of Pine and Oil creeks. It was on this island that Mr. Angier's pits were dug, and also where the first well was drilled five years later.

As a result of this purchase, the Pennsylvania Rock Oil Company was incorporated on the 30th of December, 1854, under the laws of the state of New York. In order to satisfy several residents of New Haven who took an interest in the enterprise in consequence of Professor Silliman's report, which was made in April, 1855, the property of the company was purchased by Messrs. Ives & Pierpont, and was leased by them to a new company bearing the same title and organized under the laws of Connecticut, the official residence of the company being transferred to the city of New Haven. By the 23d of March, 1857, the Pennsylvania Rock Oil Company had leased the property on Oil creek to the New Haven stockholders, who organized under the name of "The Seneca Oil Company", and E. L. Drake was engaged the following spring to go out to Titusville and drill an artesian well for oil.

Mr. Drake, called Colonel Drake on Oil creek, arrived in Titusville about May 1, 1858. At that time Titusville was a lumbering village, and the nearest point at which tools and machinery could be obtained was Erie, Pennsylvania, nearly 100 miles north, or Pittsburgh, still farther south. Drake commenced operations by attempting to sink a shaft in one of the old timbered pits once supposed to be of prehistoric origin, but hatchets of French manufacture have been discovered in or about these pits. His idea appears to have been at first to sink a shaft or ordinary well by digging; but water and quicksands continually thwarted him, and he finally resorted to the expedient of driving an iron pipe from the surface to the solid rock. This device is supposed to have been original with Drake; but if it was, he never attempted to reap any advantage from it, although it has been of great value ever since in artesian boring.

He appears to have prepared for boring during the season of 1858 by driving his pipe 36 feet to the rock and getting his engine, tools, and pump-house in order; but the men he had engaged to drill early in the season had secured another job, and the work was suspended until the following season, when Mr. William Smith and his two sons were engaged, they having had large experience on salt-wells. These men arrived at Titusville about the middle of June, bringing with them all the necessary tools for drilling. After many vexatious delays, they were fairly under way by the middle of August and had drilled 33 feet, when, on the 28th of August, 1859, the drill struck a crevice, into which it fell six inches. The following day being Sunday, Smith visited the well in the afternoon and found the drill-hole full to within a few feet of the top, and on fishing up a small quantity in a tin cup it was found to be petroleum. Such is the story of the first petroleum well. (*a*)

As soon as Mr. Watson heard the news he sprang upon a horse and hastened down Oil creek to lease the farm on which the McClintock spring was situated; but Drake telegraphed to Mr. Bissell, who thereupon bought up all the stock of the Pennsylvania Rock Oil Company that he could get hold of, and, immediately visiting Oil creek, leased large tracts of land that afterward yielded abundantly.

SECTION 5.—HISTORICAL NOTICE OF THE PETROLEUM INDUSTRY IN THE UNITED STATES SINCE THE COMPLETION OF DRAKE'S WELL (AUGUST, 1859).

The territory over which operations were conducted was for a long time confined to the valleys of the Allegheny river and its tributaries, on the supposition that the present configuration of surface was related to the strata containing the oil. For this reason wells were drilled in the valley of Oil creek from Titusville to Oil City, on French creek from Union City to Meadville and Franklin, and on the Allegheny at Tidioute. Although the coal-oil manufactories all over the country, with scarcely an exception, commenced to work petroleum instead of

a I am indebted to Henry's *Early and Later History of Petroleum*, which is indorsed by Mr. Bissell, and to many conversations with residents of Titusville and the vicinity, for the facts contained in the above narration.

coal, the production was so enormous, as compared with the demand, that the market was soon glutted and the price fell to almost nothing. An extended demand, and the partial exhaustion of the territory then being worked, led to better prices in 1865, and the immediate result was the boring of wells over an immense extent of country, from Manitoulin island to Alabama, and from Missouri to central New York. In Europe companies were also formed, and wells were put down wherever an oil-spring existed. In the United States the result was the permanent development of a small territory in southern Kentucky, another still larger in West Virginia and in Washington county, Ohio, and another in Trumbull county, Ohio, at Mecca. In Pennsylvania oil was found at Smith's Ferry, on the Ohio river, in Beaver county, and the hill region lying in the angle formed by Oil creek and the Allegheny river from Tidioute across to Titusville was explored and several localities of great richness were opened up.

Henry, in *Early and Later History of Petroleum*, pages 109 and 110, says:

The total daily product of all the wells in June, 1860, was estimated at 200 barrels. By September, 1861, the daily production had reached 700 barrels, and then commenced the flowing-well period, with an addition to the production of 6,000 or 7,000 barrels a day. The price fell to 20 cents a barrel, then to 15, and then to 10. Soon it was impossible to obtain barrels on any terms, for all the coopers in the surrounding country could not make them as fast as the Empire well could fill them. Small producing wells were forced to cease operations, and scores of operators became disheartened and abandoned their wells. The production during the early part of 1863 was scarcely half that of the beginning of 1862, and that of 1864 was still less. In May, 1865, the production had declined to less than 4,000 barrels per day.

Commencing at Titusville in 1859, the tide of development swept over the valley of Oil creek and along the Allegheny river above and below Oil City for a considerable distance; then Cherry run, in 1864. Then came Pithole creek, Benninghoff and Pioneer run; the Woods and Stevenson farms, on Oil creek, in like succession, in 1865 and 1866; Tidioute and Triumph hill in 1867, and in the latter part of the same year came Shamburg. In 1868 the Pleasantville oil-field furnished the chief center of excitement.

While this great activity was being displayed in Pennsylvania, the old salt and petroleum region in the valley of the Muskingum, in Ohio, and on the Little Kanawha, in West Virginia, was bored for petroleum, and several wells of great productiveness were obtained. In 1860 an old brine well at Burning Springs, West Virginia, that had yielded petroleum, was cleaned out, the water tubed off, and about fifty barrels of oil per day secured. In the following winter the Llewellyn well was struck at about the depth of 100 feet, and it flowed over 1,000 barrels a day. Several other good wells were secured, when, during a confederate raid, the property was destroyed and the operators were driven away. In 1864 operations were resumed, deeper wells producing a large amount of oil, and speculation and excitement ran to a high pitch. In 1865 operations were successfully undertaken at White Oak, which resulted in developing the most extensive and best known West Virginia territory. From 1860 to 1865 wells were successfully drilled on Cow run and at other localities in Washington county, Ohio.

For more than a century bitumen had been known in southern California between Santa Barbara and Los Angeles, and had also been observed floating upon the sea in the Santa Barbara channel between the islands and the mainland. Early in 1864 this region was visited by an eminent eastern chemist, who was so far misled by false local representations and by gross deceptions practiced upon him as to induce him to make a report upon this as a petroleum-producing region of great richness. This report, and others of a similar character, led to the formation of mining companies representing stock to the value of millions of dollars, all of which, it is needless to add, was lost to the *bona fide* investors. Several hundred thousand dollars were spent in boring wells, but few of them produced sufficient petroleum even to serve as a specimen, and none, so far as I am informed, paid the cost of boring. A few years of effort found the companies with depleted treasuries and no oil, and with a large amount of land and apparatus on their hands. On one estate 5,000 barrels in shooks, shipped from New York, were rotting down in a huge pile before a drop of petroleum had been obtained from beneath its surface. While these magnificent enterprises were becoming magnificent failures, more humble efforts were achieving a measure of success in driving tunnels into the steep mountain sides upon the petroleum-bearing rock. The total production of this region, however, never reached above a few thousand barrels of inferior quality per year, and the San Francisco market continued to be supplied almost exclusively with Pennsylvania petroleum shipped around cape Horn. (*a*)

From 1870 to 1880 the region between Tidioute and Oil creek has constantly become relatively of less importance when compared with the entire area of producing territory in Pennsylvania. At the beginning of this decade the production of this region had considerably lessened, and a number of new and very successful wells farther down the Allegheny river were attracting attention in that direction. Wells had been put down near the junction of the Clarion and Allegheny rivers as early as 1863 and 1864, but very little notice had been taken of them at the time; and it was not until 1868 that a successful well on the hill above Parker's landing attracted the attention of the bolder operators and led to the development of what is termed the "lower country", lying in Butler, Armstrong, and Clarion counties. In 1867 Mr. C. D. Angell had developed a very productive oil property on Belle island, in the Allegheny river, 25 miles below Oil City. While carrying forward his work he was busily investigating the occurrence of petroleum by studying the relative position of the most productive wells. He had observed in the "upper country" that a narrow belt extending across from Scrubgrass, on the Allegheny river, to Petroleum Center, on Oil creek, included many of the best wells in that region. In the "lower country" he

a Advices from the Pacific coast indicate that during the years 1880 and 1881 a petroleum interest that promises some local value has been developed in a portion of the state further north than that here referred to.

projected a similar belt, lying in a direction nearly parallel with the first, and extending from Saint Petersburg, in Clarion county, through Parker's landing, to Bear creek, in Butler county. A glance at the map (III) accompanying this report will show how Angell's so-called "belt theory" corresponded to the facts as shown by subsequent developments. As is usually the case, the majority of operators scoffed, while a few listened, and, after listening, went to work. The results have shown that the oil rock lies in belts or in long and narrow areas, having a general northeast and southwest extension, often not more than 30 rods in width, but several miles in length; that the sand rock is thickest and most productive along the axis of the belt, thinning out toward its borders, the upper surface being level and the under surface curved upward from the center; that the present configuration of the surface has no relation to the form, extent, or direction of the "belt". These facts established, and their successful application abundantly demonstrated by the remarkable success attending Angell's operations, have given a certain degree of accuracy to the development of oil territory that it never possessed before. On the other hand, they have led to very exaggerated views, some enthusiasts affirming their belief that the line of north 16° east, upon which Angell achieved his first success, governed the direction and extent of territory containing oil from Canada to Tennessee. I shall again refer to the facts upon which Angell's theory is based in my chapter on the "Origin of Bitumens". (*a*)

Angell kept his own counsel at first, and obtained a sufficient number of leases on favorable terms to insure his financial success; but the plan upon which he worked became apparent from the character of his operations, and others followed, or attempted to follow, his example, and wells were drilled across the country to the southwest of Parker's landing into Butler county, and often miles in advance of any territory hitherto proved profitable, until a tract was more or less clearly outlined about five miles in breadth and thirty-five miles in length, the principal axis of which lay in the general direction north 22° east. Other less extended belts lying generally parallel to this will be noticed by glancing at the map (III).

During the early years of this decade, when Angell's efforts and sagacity were being rewarded in the lower country with success in a most substantial form, other operators struck out from the "upper country" of Oil creek in a general northeast direction, some on a line north 16° east, others north 22½° east, and others on still other lines, often traced over the forest-covered hills of that region with a compass, and located their wells in the expectation of finding other sand-bars of the ancient sea from which the oil would rush to the surface. They finally reached the town of Bradford, in McKean county, a locality which some thought could never produce oil.

It was not the first attempt at well-drilling that obtained oil in the neighborhood of Bradford. In 1862 the old Bradford well, since known as the Barnsdall well, was drilled to a depth of 200 feet with a spring-pole and then abandoned. In 1866 the citizens of the village of Bradford concluded to club together and sink the Barnsdall well deeper, and it was drilled to a total depth of 875 feet, or to within 150 feet of the Bradford producing sand. In 1865 F. E. Dean and brothers drilled a well in the valley of Tuna creek, on the Shepherd farm, near the present site of Custer City, 160 feet of drive-pipe being used, and the hole being drilled to 900 feet, but it was abandoned when over 200 feet above the top of the oil-sand.

The next well was drilled by the Dean brothers on the Clark farm, at Tarport, and drilling was stopped at a depth of 605 feet, or over 400 feet above the top of the oil-sand. All of these wells were drilled with the expectation of finding the Venango county oil-sand at about the same depth below water-level as at Oil City, but they were all failures.

The first well sunk to the Bradford sand was drilled by Mr. James E. Butts and others, under the name of the Foster Oil Company, on the Gilbert farm, 2 miles northeast of Bradford. "Slush oil" was found at a depth of 751 feet, and in November, 1871, producing sand was struck at 1,110 feet. The daily production was 10 barrels, and from the time this well was struck to December, 1874, no wells were drilled to amount to anything. On December 6, 1874, Messrs. Butts and Foster struck the oil-sand on the Archy Buchanan farm, 2½ miles northeast of Bradford. This well started off with a daily production of 70 barrels, and was really the first that attracted attention to the possibility of finding a profitable oil district in the county. In December, 1878, four years from the completion of the Butts well, the average daily production of crude oil was 23,700 barrels, or about four-sevenths of the total daily production of the state of Pennsylvania, while in December, 1880, two years later, and six years from the completion of the first well, out of a total average daily production for the Pennsylvania oil-fields of 72,214 barrels, 63,000 barrels were yielded by the Bradford field alone.

During the year 1879 there were 475 wells drilled to the Venango sands in the counties of Warren, Venango, Clarion, and Butler. Of this number 122 were dry holes, or produced no oil, being 25.7 per cent.

In the Bradford or northern district there were during the same year 2,536 wells drilled to the Bradford oil-sand, of which number but 76 were dry holes, or only 3 per cent., being nearly 23 per cent. less than in the Venango or western district.

The average daily production for the first month of the wells drilled in the Bradford sand was about 20 barrels, while for the wells in the Venango sands it did not attain that amount. Some of the wells drilled to the Venango third-oil sand have produced from 2,000 to 3,000 barrels of oil per day, while the largest well ever found in the

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a See page 70.

Bradford district has not exceeded as many hundred. The largest individual wells have been located in the western district; the largest average wells in the northern district. Since the beginning of the year 1875, when the Bradford oil horizon was discovered, there have been 6,249 wells drilled in the district, of which 236 were dry holes, or 3.77 per cent. From the most authentic statistics which I can gather in the western district, about one-fourth of the wells that have been drilled in the Venango sands, since their discovery in 1859, have proved dry. When we take these facts into consideration, we can readily understand why there should have been 2,536 wells drilled in the northern district to only 475 in the western in 1879. (*a*)

During 1880, as undrilled territory became more scarce in the Bradford field, what are termed "wild-cat" or test wells were drilled both to the northeast and to the southwest of Bradford, and the result has determined two areas, one near the city of Warren, and another around Stoneham, both in Warren county, Pennsylvania. To the northeast an area not yet outlined has been determined around Richburg, Cattaraugus county, New York.

Forty-five years ago M. C. Read, esq., now of Hudson, Ohio, lived in Mecca, on the east side of Mosquito creek. It had been observed for a long time that petroleum gushed out when stones were removed from their places along the bank of the creek, and as it frequently appeared in wells it was considered a nuisance. In the spring of 1860, when there was great excitement in eastern Ohio over the oil in Pennsylvania, Mr. Read mentioned to some persons what he knew about the oil-springs in Mecca, and it was only a few days thereafter before property was being leased in that place on a royalty of from one-tenth to one-quarter, and in a year all available property on the west side of the creek and some on the east side had been taken up.

Wells were bored rapidly, yielding from 10 to 20 barrels, and in some cases were so near together that one sucked air from the other when pumped. Thousands of barrels of oil were taken out yearly for a few years, when a large part of the wells became exhausted, many of them were abandoned, and the excitement subsided. In 1864 it was renewed for a short time, and Pennsylvania parties bought up all the land on the east side of the creek and obtained a few good wells, but they soon failed. Since that time a few persons have been engaged in drilling new wells and pumping the old ones, for the most part spending what they got on good wells in drilling others which produced nothing. In the opinion of those best qualified to judge, Mecca oil operations have netted nothing, or more probably have resulted in a loss. The operators now make a living, all money earned over and above being spent in putting down new wells.

Near Power's Corners there was in early times an old shaft which tradition credited as the work of a prehistoric race. Such an origin is not probable.

At Belden, in Lorain county, Ohio, it is reported that one Reuben Ingersoll sunk a well for salt in 1818 or 1819 on the Root farm, but so much oil came with the brine that the well was soon abandoned. The oil for a long time was skimmed off and sold as a medicine. Many years afterward, in sinking a hole for the post for a flood-gate to a mill, petroleum appeared at the bottom, and occasionally it appeared in other excavations.

It is claimed that the first well was bored here for oil in 1858, but on what authority I do not know. It is said to have been bored 500 feet deep by a Mr. Harper and to have struck oil at 50 feet. In 1860 a Mr. Gardener sunk Harper's well to 1,200 feet and abandoned it.

Other wells were put down soon after, and one of them—the old Crittenden well—in 1862 pumped by hand, wind-mill, and steam-power 65 barrels. A few wells at Liverpool have a similar history.

A Mr. Thoms in 1850 gathered oil from holes dug in the sand on a bar of the Ohio river near the mouth of Little Beaver creek, Beaver county. The first well was the Fenton well, drilled in 1860, close to the mouth of Dry run. This well was 170 feet deep, and yielded 14 or 15 barrels of heavy lubricating oil. They then went down along the river 575 feet and on Island run 600 feet, and reached a fine, close sand. Some wells were carried down 1,100 or 1,200 feet to the second sand, yielding a little oil. Wells in this section have never been drilled 1,500 to 1,600 feet to the third sand. This territory is between three and four miles square. Some oil has also been obtained at Beaver creek and Rochester, in the same county; but the principal development in this section is confined to a small territory immediately north of Smith's ferry, and has occurred since 1878.

Section 6.—HISTORICAL NOTICE OF THE RUSSIAN PETROLEUM INDUSTRY.

There are five foreign oil-fields that have attracted attention and that have produced more or less oil in commercially valuable quantities. They are the region of the Caucasus, Galicia, Canada, Japan, and Peru. Of these, the first mentioned is altogether the most important so far as present information indicates. Next may be placed Canada; but as regards the relative importance of the others it would be difficult to decide.

The Russian fields lie in two districts, one at either extremity of the Caucasus. The western, on the Black sea, is the Kouban, on a river of the same name; the eastern is the Baku district, on the peninsula of Apscheron, extending into the Caspian sea, and on which the city of Baku stands.

The Kouban district is situated on the northwestern slope of mount Oshten, which is the most western peak of the Caucasus, 9,000 feet in height. Its area is about 250 square miles. Operations were commenced here in 1864

a I am indebted for the major portion of this statement in reference to the Bradford field to two papers by Charles A. Ashburner, esq.—the first read at the Baltimore meeting of the American Institute of Mining Engineers, February, 1879; the second read before the American Philosophical Society, March 5, 1880. P. A. P. S., xviii, 419; T. A. I. M. E., 1879; P. A. P. S., 1880.

by the Russian colonel Novosiltsoff, who had a monopoly of the petroleum industry of that region for more than twelve years. He sunk his first well at Peklo, near the coast of the Black sea, and after many borings, with varying success, in different parts of the district, he became so heavily involved that to save him from bankruptcy the government placed the petroleum interests under a curatorship.

From these exploitations of varying depth, large quantities of excellent petroleum of specific gravity from 38° to 48° Baumé have been obtained.

The most remarkable well was obtained at Kandako in 1866. At a depth of only 40 feet from 10 to 12 barrels of oil per day were yielded. At a depth of 123½ feet the first flow of oil appeared and yielded 125 barrels of oil per day, throwing it 14 feet high. The well was mismanaged and choked, and when finally reopened and sunk to 182 feet, a flow of oil rose to 40 feet high, and gave 250 barrels per day. It was again choked and finally deepened to 242 feet, when the oil again flowed with great power and violence, yielding several thousand barrels per day, and continued its spontaneous action for eighteen months. (*a*)

This management came to an end in 1877, on the breaking out of the last Russo-Turkish war, when the whole district of the Kouban was abandoned. In 1879 the larger portion of the district, amounting to 1,500,000 acres, was leased to Dr. H. W. C. Tweddle, with private estates amounting to 90,000 acres additional. During the years 1879 and 1880 great activity has prevailed in preparation for an extensive development of oil with all of the appliances in use in Pennsylvania for obtaining, handling, and refining petroleum.

Concerning the history of petroleum production at Baku, Consul Dyer wrote, on August 10, 1880, as follows:

From time immemorial oil has been known to exist at Baku, and for generations the natives have taken it for greasing their vehicles, preparing skins for wine, etc., and for use in the southern countries for embalming the dead, and even in some cases for illuminating purposes. Their wants were, however, small, and the surface production was sufficient.

The wells were rather receptacles for the surface oil than otherwise, as they were simply holes dug a few feet deep in the earth.

From the time of the Russian occupation of the country in 1723 down to 1825 this industry remained almost neglected. From 1813 something was done, but nothing of importance, and the total revenue to the government arising from it was less than $40,000 per year. From time to time private persons took the privilege, and at times the crown worked them to some extent. The price charged for the oil was as high as 4 rubles per pood, and thus the industry was destroyed. (*b*)

It was about 1832 that the industry began to assume anything like business proportions; but even then it was managed so badly that it remained very insignificant. A few wells were dug (as wells for water are dug), and the government even refused permission for an enterprising lessee to work with any kind of boring tools, the officer replying that such things had been tried, but that they had not succeeded, and consequently could not be tried again at Baku.

In 1850 the government gave a monopoly and limited the selling price of crude oil to 45 kopecks the pood, and received the sum of 200,000 rubles for the privilege. This monopoly was farmed out every four years to the best * * * bidder. In 1868 a commission was formed to take into consideration the industry. In 1872, in pursuance of its recommendations, the territory upon which there were surface indications was divided into plats of 25 acres each, and sold to the highest bidder by sealed proposals. By this time the field had attracted much attention, and the parcels were disposed of in some instances for enormous prices. In most cases, purchases were made by persons who had not the means to work their possessions, nor the experience had they possessed the capital. They, however, held on to their lands, and capital and experience were thus kept away, and the industry was worked in the most crude and unsatisfactory manner.

The product of the refineries was so bad, and the market so small, that there was not energy enough engaged to bring on a crisis in the industry. The government had placed an excise tax, which, under the circumstances, was unbearable, and for a time previous to 1878 the operators were upon the verge of ruin. No work was done except to fill contracts previously made. At Nishni-Novgorod there was in store more than one and a half millions of poods, almost 200,000 barrels, unsold, and the price had gone down from 3.50 to 1.30 rubles per pood. The government then removed the excise tax, and now there remains only a small tax collected by the town of Baku.

The real birth of the industry may be said to be the year 1872, when the lands passed into private hands. There have been since that time great but insufficient energy and activity displayed. The operators have no relations with each other. * * * Many small owners, for want of means to work their property, have been obliged to sell, and some capitalists have entered simply as refiners, buying the crude oil for that purpose. Some of these refineries have grown to large proportions, and the principal ones are now making such improvements and changes as to make them first-class establishments, capable of enormous and thorough work.

He states further, as follows:

The territory now worked does not exceed six square miles. The principal field is at Balaxame, 9½ miles northeast of Baku, covering a territory of, say, 3½ by 1½ miles. Two miles south of Baku is a small field at Bēbēabat, on which there are some 25 wells. This is a very small territory, say three-fourths of a mile square. Ten miles southeast from Baku is an island. It is certain that oil exists there, but in what quantities is not known. Within a radius of 50 miles there are constant surface indications, and even some small wells.

In 1850 there were in all 136 wells. In 1862 there were 220, and in 1872 there were 415. These were wells dug as water wells are. In 1871 the first well was *bored*. In 1872 there was 1; in 1874, 50; in 1876, 101; in 1879, 301 bored wells in the district. The other wells had entirely ceased to be worked. During the year 1879, and so far in 1880 (August), there has been very much work done, but the exact figures are not attainable. The business is in a most confused condition now, in consequence of the changes that are being made. Many new wells have been commenced, and a very large number of those previously worked are being drilled deeper. If the figures given may be relied upon, that is, 301 wells up to 1879, it may now, perhaps, be said that on the 1st of July, 1880, about 500 wells had been commenced. Many of them are not completed, and some have been abandoned.

I have purposely omitted reference to the more or less highly colored accounts of the Baku "field of fire" and the "Persian fire-worshipers and their temples". The "field of fire" is described by Gruner (*c*) "as a broad expanse filled with fissures, from some of which inflammable gas escapes, and from others naphtha". Another speaks of it as a "wonderful sight; of green fields and waving corn, in the midst of which the removal of a foot or two of earth will reveal a jet of gas that will raise an enormous blaze if set on fire". (*d*)

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a Consular Reports No. 1, October, 1880.

b Ruble, $0.56; pood, 36 pounds.

c *Ann. Génie Civil*, iv, 845.

d Churchill, British consul to Resht, Persia.

SECTION 7.—HISTORICAL NOTICE OF THE PETROLEUM INDUSTRY OF GALICIA.

The petroleum fields of Wallachia, Moldavia, and Galicia lie upon the southern, eastern, and northern flanks of the mountain system that incloses Hungary from Russia and the plains of the Danube. This system embraces the Transylvanian Alps, the Siebenbürgen, and the Carpathians.

Oil springs have flowed in this region from time immemorial, and the oil has been collected and used by the inhabitants of the country and devoted to many of the rude and uncultivated wants of a people remote from the centers of civilization. In 1810 Josef Hecker and Johann Mitis obtained petroleum in Drohobycz district, and made a trial of the distilled and crude oil, which was obtained from dug wells and afterward treated in stills; but having worn out their still in 1818, their works were closed. In 1840, in the Stanislow district, there were 75 dug wells and 6 establishments for the manufacture of wagon-grease. In 1853–'64 Schreiner boiled down petroleum and made a very superior article of grease, and his successor condensed the distillate and used it for illuminating purposes. The industry since that time, although conducted in a small way, had steadily increased until 1860–'65. (*a*)

Since 1860 a great deal has been written on the Galician oil-fields, and several spasmodic attempts have been made to find remunerative employment for capital in their development. This was especially the case in 1865, when the expansion of the production of Pennsylvania led to so many enterprises of a more or less experimental nature all over the world.

There are three localities particularly noted for their petroleum product. These are the neighborhood of Sandecer, in west Galicia; that of Bōbrka, near Dukla, Sanoker, and Samborer, in middle Galicia; and Boryslav, in east Galicia. The latter locality is also celebrated for its production of ozokerite. The localities in Roumania that are now principally associated with petroleum are Sarrata, Bacan, Dimbovitsa, Prahova, Burzen, Moniezta, Plojezti, and Baikoi.

The oil was originally collected, as in other localities, from the water of the springs, with which it flowed from the crevices in rocks. It was afterward obtained from wells or shafts that were dug, and in Galicia and Roumania it is at present obtained in that primitive manner. Later the shafts were connected by galleries, forming what are called "complex mines" (complex Gruben) in Galicia.

The exploitations for oil at Mraznica consist of about 70 shafts in the upper part of the valley of Tiesmienka, the lowest row of shafts lying on both sides of the declivity of the Bachspiegels, with a second and a third row above them. They consist of the "old" complex mines, consisting of about 40 shafts, and the "new" complex mines, consisting of about 30 shafts. The older "complex mine" is going on 12 years old, having originated when the oil fever agitated Galicia. The first shafts were sunk by a Jewish company near an oil-spring to a depth of 100 meters (328 feet) with very satisfactory results, in consequence of which, and in order to control the production, they sunk many other shafts in the immediate neighborhood as soon as possible, and thus copied the Boryslav method of operation in the most destructive manner. The consequence was that they finally obtained from about 40 shafts the same quantity of oil that they could have had from 10 exploitations. A second oil-level, not yet reached, is supposed to exist, but the shafts have only penetrated 100 to 150 meters (328 to 492 feet). The largest yield from a single shaft is said to have amounted to 40 barrels of crude oil per week. Through ten years the most of the shafts have had an average flow of about 4 barrels per week; yet a single shaft is said to have yielded a net profit of 200,000 gulden ($100,000), and has yielded petroleum for ten years up to 1878.

After a period of ten years the yield of oil decreased to such an extent that the enterprise became unprofitable. This caused the projector of the Jewish enterprise to attach the new "Gruben complex", consisting of 30 new-dug shafts, which likewise lay near each other in a compact mass, to the immediate upper half of the old shafts. In November, 1878, these shafts were sunk 20 to 50 meters (65 to 164 feet); yet they yielded no traces of petroleum particularly worthy of note. The extensive development of gas of the "old complex" was also entirely wanting. This failure is explained by assuming that the new shafts happened to lie within the circle already exhausted by the "old complex". Hence the petroleum industry in Mraznica must come to an end; yet, toward the close of 1878, 5 shafts still yielded about 14 barrels weekly. The long duration of the flow from these shafts is remarkable (ten years), while other springs in Galicia only flow an average of five years. (*b*)

Mraznica is in east Galicia. The facts set forth by Herr Walter explain why Consul-General Weaver reports December 30, 1880, that, of the yearly product of 100,000 barrels, produced in Galicia, two-thirds are at present obtained in west Galicia, in the vicinity of Grybow, where, during the census year, Mr. James Corrigan succeeded in establishing an American refinery. In a letter dated October 9, 1881, Mr. Corrigan states that a new well, yielding 75 barrels daily, had been struck at Slaboda, near the boundary of Bukowina (east Galicia), and that consequently great excitement prevailed.

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a Ost. Zeit. f. Berg- und Hüttenwesen.

b Abstract of a portion of an article by Bruno Walter on "The chances of a petroleum production in Bukowina". J. K. K. G. R., xxx, 115 (1880).

Section 8.—HISTORICAL NOTICE OF THE PETROLEUM INDUSTRY OF CANADA.

The productive oil-fields of Canada lie in the county of Lamberton, in the western part of the province of Ontario, and principally in the township of Enniskillen. From the earliest settlement of the region "a dark oily substance had been observed floating on the surface of the water in the creeks and swamps. No matter how deep the wells were dug, the water was brackish and ill-smelling, and in some localities totally unfit for use; while a surface of black, oily slime frequently arose an inch thick, as cream rises on new milk. Here and there in the forest the ground consisted of a gummy, odoriferous tar-colored mud, of the consistence of putty. These places were known by the name of 'gum-beds', and in two or three instances were of considerable extent". (Henry's *Early and Later History of Petroleum*, p. 130.)

Operations were commenced there as early as 1857 by one Shaw, who dug an ordinary well, as for water, and after several days of digging struck a tremendous flow of oil, which ran in a stream into the creek. The usual phenomena attending such a discovery followed; land was bought and leased, more wells were dug, and oil flowed; they gathered what they could and wasted the remainder; fortunes were made and lost, and after a time, in 1864, the town of Oil Springs contained 3,000 inhabitants.

Flowing wells were struck here in 1862, and some of them proved the most prolific on record, rivaling those of the region around Baku. These great wells were exceptional, and the average yield has been comparatively small. The region over which borings have proved the existence of oil in paying quantities is about 50 miles north and south by 100 miles east and west, and within this range Petrolia, Bothwell, and Oil Springs have produced nearly all of the oil. The latter had the largest wells, though the former now produces more than nine-tenths of the amount at present obtained. Petrolia is about 16 miles southeast of the outlet of lake Huron, Oil Springs 7 miles south of Petrolia, and Bothwell about 35 miles from Oil Springs.

The petroleum of Canada contains sulphur and is difficult to refine, but its production has been fostered, and it supplies a large demand throughout the British provinces.

Section 9.—HISTORICAL NOTICE OF THE JAPANESE PETROLEUM INDUSTRY.

The knowledge of rock-oil in Japan is of great antiquity. In B. S. Lyman's reports (1877) appears the following:

It is said in the Japanese history called Kokushiriyaku (I am told) that rock-oil (or "burning water") was found in Echigo (in Niphon) in the reign of Tenjitenno, which was 1,260 years ago, or about A. D. 615; and that was probably at Kusôdzu, where there are very old natural exposures as well as dug wells. The name of the place, Kusôdzu, is the name given in the country to rock-oil, and means stinking water; and the very fact that the word is by contraction so much changed from its original form, Kusai midra, shows of itself considerable antiquity.

In the Miyôhôji and Kusôdzu oil region there are (beside a much larger number of old, abandoned wells) about 178 productive wells, which altogether yield about 4⅗ barrels a day, making an average of about 1 gallon a day for each well. The best well is at Machikata, and yields about half a barrel a day. The best of the former wells was at Kitakata, and for fourteen days (in 1871) it yielded a daily average of 19 barrels, but after that only about 8 barrels a day. The deepest productive well of the region is 122 fathoms deep.

Reviewing all the Echigo oil-fields, we find that there are in all 522 productive wells, of which the deepest is 122 fathoms (732 feet) deep, the greatest yield is about 1.2 barrels a day, and the total yield about 26 barrels a day, giving an average of about 2 gallons a day for each well. Such a yield, if kept up through the whole year, summer and winter, would amount for all the wells together to 9,500 barrels a year, worth, at 12 gallons to the dollar, $31,650.

At Shinano, on the other hand, the yield is far smaller. There are in that province, in spite of the numerous traces of oil and gas, only 22 productive wells, of which the deepest is 57 fathoms (342 feet) deep, and the best has a yield of 2½ barrels a day; and the total yield is a little over 5 barrels a day, or an average of 9½ gallons a day to each well; or, in a year, 1,900 barrels altogether, worth about $6,250.

The whole yield of the two provinces, then, is about equal to that of two average Pennsylvania oil-wells. Yet two or three cases have occurred in Echigo of a yield of 15 to 19 barrels a day for a few days when the wells were new. At Miyôhôji they talk of having had a profit of $70,000 to $80,000 from a single well; and the general estimate of the yield of that field has been high.

Such was Mr. Lyman's (geologist of Japan) estimate of the product of the most fruitful oil-fields of Japan in September, 1876. Many other localities have been explored for petroleum with similar results; but the introduction of American refined oil at present prices has nearly destroyed the domestic trade, and has completely arrested the production.

In the very elaborate report made by Consul-General Van Buren in 1880 no mention is made of any domestic production of petroleum, although Consul Stahel, of Hiogo, shows that the imports of American refined petroleum into Japan have increased from about 1,000,000 gallons in 1872 to nearly 18,000,000 gallons in 1880. Hiogo has been one of the most important centers of the native petroleum trade, it having had a refinery.

Section 10.—HISTORICAL NOTICE OF THE PERUVIAN PETROLEUM INDUSTRY.

Previous to the outbreak of the war between Chili and Peru the prospect of a large development of petroleum in Peru was very flattering. The following statement of operations there has been widely copied, but I cannot vouch for its accuracy, as I have not been able to verify it:

Mr. Prentice, the Pennsylvania oil operator, in 1867, paid Peru a visit. A well was put down near Zorritos. At the depth of 146 feet a volcanic formation was reached by the drill, and oil was found. The well pumped 60 barrels a day. A second well was put down. Oil was reached at a depth of 220 feet. The yield rapidly declined from 12 barrels to 7 barrels a day. Mr. Prentice was satisfied that the

region would prove productive, but he held his own counsel. In 1876 he succeeded in securing the control of the entire estate for the purpose of producing oil. In that year the second well mentioned above was drilled to the depth of nearly 500 feet. The tools struck a vein of oil-bearing sandstone, and immediately sank 10 feet. This was the first finding of the sandstone. The strike was followed by a column of oil that filled the 6-inch casing and was thrown 70 feet in the air. In attempting to control the great flow by inserting tubing in the well the inexperienced employés let the tubing drop to the bottom. The side caved in soon afterward and stopped the flow. The well is still plugged. Mr. Prentice says its capacity will be 1,000 barrels a day. Another well of his near the above has been in use for three years. It has never yet been torpedoed or reequpped. It yields 600 barrels a day. Mr. Prentice's experiments have proved that the deeper the wells are sunk the larger the yield is. At 600 feet he declares that a well in his Peruvian regions will pump 5,000 barrels a day. Back in the mountains some of his men have struck a vein of petroleum by merely digging a pit 28 feet deep. Several of these pits have been dug. Oil accumulates in them in paying quantities. Mr. Prentice has a refinery at Zorritos. Its capacity is 200 barrels; this he is now enlarging. There were shipped from the Pennsylvania oil regions in 1870, 1,085,615 gallons of oil to Peru, Chili, and Ecuador. Refined oil brings 25 cents a gallon in Peru and its neighboring states.

I have been informed that since the outbreak of the war nothing has been done in reference to this industry.

Section 11.—HISTORICAL NOTICE OF THE ITALIAN AND OTHER PETROLEUM INDUSTRIES.

I am indebted to Professor P. E. DeFerrari, C. E., of Genoa, for the following statement concerning the petroleum interests of Italy. His letter was dated Iglesias, Sardinia, December 22, 1881, and in it he says:

There are in Italy two large districts with petroleum-bearing strata: one in the north, on the southern borders of the Po valley; the other in the south of Italy. Unfortunately, in spite of extensive workings and a considerable amount of money employed in searching for mineral oil, no satisfactory result was obtained.

The chief localities where petroleum and its allied products are met with are—Po valley: Rivanazzano, province of Voghera; Riglio, province of Piacenza; Miano, in the Caro valley of Parma; Sapuolo, in the Secchia valley of Modena. South Italy: San Giovanni Incarico of Caserta; Coco, in the Pescara valley of Chieti.

In the first district the oil is of a very good quality, very pure, largely diffused in the rock, but occurs in strata chiefly of clay and argillaceous sand, which, because of their little permeability, do not permit the free exit of the oil when wells are dug in the ground. The geological range of the strata is the Miocene and Pliocene periods. Some geologists believe that below the above-mentioned strata there may be other strata which would yield large quantities of petroleum when pierced through with wells. It must be stated that these strata have not been found, even in those places where borings of 250 and even 400 meters have been opened (820 to 1,312 feet).

Six different societies have worked the petroleum springs of North Italy from the year 1866 to 1874, but without success. Several wells reached the depth of 200 meters (656 feet), but no large veins of petroleum were met with, and the works were abandoned. In the valley of Pescara, South Italy, there are also petroleum springs, with bituminous products. At Coco borings of great depth have shown the existence of some oil veins, but of little importance. At San Giovanni Incarico several veins of some hundred liters every twenty-four hours were found, but they have no industrial importance. Lately an Italian and French society, with large capital, and Canadian workmen and machinery, explored the ground at Rivanazzano and at Coco. They opened four wells 200 meters deep in the north; one 400 meters in the south (Coco); but the working was given up for deficiency of money. The whole product of petroleum in Italy does not exceed 300 tons a year, and it is chiefly collected in large and shallow wells by the country people, and used on the spot. No machinery worth mentioning, but small pumps, are used, and in most places the work is done simply by hand.

At Sapuolo and Salsomaggiori the gas which comes from crevices in the ground is collected and burned for industrial purposes. In the south of Italy bituminous clay is distilled and petroleum condensed in small quantity. The annual importation of petroleum into Italy is 50,000 tons, and its value is 14,500,000 francs.

This letter states the condition of the petroleum industry as related to modern methods of exploitation, and prices as governed by the enormous supply furnished at present by the United States; but petroleum has long been known in the valley of the Po, and many of its smaller towns have been lighted by it. The exceptionally fine quality of the petroleum of that region made it possible to use it without refining.

The earliest mention of petroleum from this region is by François Arioste, who cured men and animals afflicted with itch with petroleum which he had discovered in 1460 at Mont-Libio, in the duchy of Modena. (*a*) Agricola also mentions it in the middle of the sixteenth century. (*b*)

Many other localities will be enumerated in the succeeding chapter as furnishing petroleum, but those mentioned are the only ones that have furnished petroleum to the commerce of civilized nations.

The historical development of the petroleum industry may be summed up as follows: In many regions, and for immemorial periods, petroleum gathered from natural springs and dug wells has been used in medicine, and in a rude way as an illuminating agent. In China artesian wells have been bored for brine and for natural gas, and the latter was used to boil brine for centuries before the Christian era. In the United States artesian borings made for brine had furnished petroleum in enormous quantities thirty or forty years before any use was known for such a supply. The development of the coal-oil industry between 1850 and 1860 led to experiments upon petroleum as a substitute for the crude oil obtained from coal, and with the success of those experiments (1859) came a demand for petroleum that led to Drake's attempt to procure the oil directly by boring.

The success attending the oil industry in Pennsylvania during the first four years of its existence led to the organization of companies all over the world for the purpose of drilling test-wells wherever springs of petroleum were accessible. In some localities they were successful; in others only partially so; while in the majority of instances they were failures, or were found inferior to the primitive dug wells. The continuously increasing and enormous production of the United States, and the consequent depreciation in value of all the products manufactured from petroleum, has led to the almost complete control of that trade by American manufacturers, Galicia and the Caucasus at the present time being their only competitors, and they only to quite a limited extent.

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a His book was published in 1690 by Jacob Oliger; *Comptes-Rendus*, ix, 217.

b *Comptes-Rendus*, ix, 217.

CHAPTER II.—THE GEOGRAPHICAL DISTRIBUTION OF PETROLEUM AND OTHER FORMS OF BITUMEN.

SECTION 1.—THE OCCURRENCE OF BITUMEN IN THE UNITED STATES.

The following chapter has been prepared for the purpose of showing the localities upon the earth's surface at which bitumen occurs, and great care has been taken to secure the most accurate information regarding the United States. For this purpose letters of inquiry have been addressed to the state geologists of all the states with which I am not personally acquainted, and to the geologist in charge of the geological survey of the United States. To these official sources of information has been added a large amount of personal inquiry and correspondence.

The map of the world (I) has been prepared to show the location of the areas producing bitumen. These areas are unavoidably exaggerated in size, and many localities of minor importance are omitted.

The map of the United States (II) shows the localities within the United States that have produced bitumen of any kind. Many of these areas are also unavoidably exaggerated in size.

The large map (III) shows the areas in Pennsylvania and New York that have proved commercially valuable. This map has been prepared from actual surveys, many of which were undertaken expressly for parties engaged in producing oil. The areas tinted yellow are believed to be substantially correct as regards both location and outlines. The streams were plotted with every attention to accuracy, and are believed to indicate the water-shed and lines of greatest elevation. The dates beneath the names of towns indicate the period at which the locality was yielding its maximum production. The red lines indicate the main pipe lines, and the broken blue lines indicate in a general way the outline of territory over which wells or natural springs have yielded petroleum or gas, but in most instances not a sufficient amount of petroleum to be profitable.

Map IV represents the areas at the White Oak district, West Virginia, drawn from actual surveys.

Map V shows the location of oil-wells in the valley of the Cumberland river in Kentucky and Tennessee, drawn from actual surveys.

Map VI represents in a general manner the localities in southern Ohio, West Virginia, and Kentucky that have produced bitumen.

Map VII represents in a general manner the localities in Louisiana and Texas that have produced bitumen.

Map VIII represents the localities in Michigan and Canada that have produced bitumen.

STATES AND TERRITORIES FROM WHICH NO BITUMEN HAS BEEN REPORTED.

Maine.	Maryland.	Mississippi.	Montana.
New Hampshire.	Virginia.	Arkansas.	Idaho.
Vermont.	North Carolina.	Iowa.	Washington.
Massachusetts.	South Carolina.	Wisconsin.	Oregon.
Rhode Island.	Georgia.	Minnesota.	Nevada.
Delaware.			

STATES AND TERRITORIES IN WHICH SOLID BITUMENS OCCUR.

CONNECTICUT.—In the valley of the Connecticut river solid bitumens have been observed filling thin seams and veins in eruptive rocks. (*a*)

NEW YORK.—In the eastern portion of the state, in the region of eruptive and metamorphic rocks, veins occur similar to those reported from Connecticut. (*b*) In some of the cavities of the New York limestones the crystals which line them are covered with a substance, black and shining, with the fracture and appearance of anthracite.

NEW JERSEY.—Veins are reported in the trap of New Jersey filled with a bituminous mineral. (*c*)

WEST VIRGINIA.—In Ritchie county, West Virginia, on McFarland's run, a small tributary of the south fork of Hughes' river, which enters the Little Kanawha, is found a vein of bituminous material, called asphaltum, which is without doubt closely related to petroleum and other forms of bitumen, but in precisely what manner has been a subject of much controversy. This vein cuts the nearly horizontal sandstone almost at right angles and stands vertical to the horizon. Very extensive mining operations were commenced upon the vein, but the mass was soon worked down to the lower level of the sandstones, and was found to pinch out in the shales beneath. It presented all of the appearances of an eruptive mass. The material was found to be exceedingly

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a J. C. Percival on "Indurated Bitumen", *Geol. of Conn.*, A. J. S. (3), xvi, 130.
b L. C. Beck, A. J. S. (1), xlv, 335.
c J. C. Russell, A. J. S. (3), xvi, 112.

valuable for enriching gas, for which it was chiefly used; but a thickness of several hundred feet of shale, in which it was almost entirely wanting, prevented continuous working. Other smaller but otherwise similar veins occur in the neighborhood. (*a*)

TEXAS.—Near the mouth of the Brazos river and in other parts of Texas beds of asphaltum occur, evidently resulting from the decomposition of petroleum; but so far as I have been able to learn they have no commercial value.

NEW MEXICO AND ARIZONA.—In these territories beds of asphaltum are reported. They have no other than a local value.

UTAH.—In this territory, in the Sanpete valley, southeast of Salt lake, is said to be a deposit containing ozokerite similar to that found in Galicia. Also on the banks of the Green river veins are said to occur resembling the grahamite found in West Virginia. Although I have seen specimens which were said to have come from both of these localities, I have never met any detailed description of them. Neither deposit has yet any commercial value.

CALIFORNIA.—This state includes a large area which furnishes asphaltum, much the larger proportion being the product of the decomposition of petroleum, while the remainder occurs in veins that are evidently eruptive, (*b*) the former occurring in beds of greater or less extent on hillsides or gulch slopes below springs of more fluid bitumen. These deposits are scattered over the country between the bay of Monterey and San Diego, but are chiefly observed west and south of the coast ranges between Santa Barbara and the Soledad pass. In the aggregate there are thousands of tons of asphaltum scattered over this region of every possible degree of purity; but it is so difficult to handle, and so little is concentrated in one place, that little use has thus far been made of it.

The case is quite different, however, with the deposit at Hill's ranch, on the coast above Santa Barbara. Here eruptive masses that have been very fully described by Professor J. D. Whitney and myself (see note *b*) occur in such quantity that it has been obtained in cargoes for use in San Francisco. The asphaltum of this locality is solid and homogeneous in appearance, but it really contains 50 per cent. of sand, so fine and in such complete admixture as to make the material superior for pavement to any artificial mixture that can be produced. I have never been able to obtain even an approximate estimate of the quantity that this locality has furnished.

KENTUCKY.—Asphaltum is reported in Johnson county, on the tributaries of the Big Sandy river. I have never seen any of this asphalt, but I am inclined to think it is also more closely related to the gum beds of Canada, above mentioned.

TENNESSEE.—Asphaltum is reported in cavities and prisms in the Trenton limestone in middle Tennessee in small veins rarely an inch in thickness. The amount is insignificant.

OTHER LOCALITIES.—Asphaltum is also reported from other localities, in Missouri and Kentucky, but I have never seen any of the material, and from all that I have been able to learn regarding the deposits they resemble the so-called gum beds of Canada, which really consist of a mass of mud or soil saturated with petroleum, rather than of pure and solid asphaltum. Such mixtures of oil and mud are often met around oil-wells in any of the productive districts where the waste oil has soaked the ground about the derricks.

STATES AND TERRITORIES IN WHICH SEMI-SOLID BITUMEN (MALTHA) OCCURS.

This material issues from so-called tar-springs, and is found almost or quite exclusively within the southwestern portion of the country. I have seen but a single specimen from one of the interior counties of Texas. A letter of inquiry, addressed to the secretary of state of Texas, was referred to Mr. N. A. Taylor, who replied:

> The tar-springs in Burnet county discharge a good deal of petroleum. The wagoners gather it to grease their wagon wheels. It is probable that borings there would get a good supply of oil. It appears on the surface of nearly all the springs at Sour lake. In days past it has evidently exuded from the ground at that place in great quantity, for there are some acres just below the lake almost completely covered with the consolidated stuff, or asphalt, the thickness of which I don't recollect, but no doubt it is very thick in some places. An attempt was made there to bore for the oil, but after penetrating the ground to some distance a great explosion occurred, and the fellow was afraid to try it again. I think some borings have also been made in Nacogdoches county. There is also a small lake in Marion county, where oil covers the water, and where there is also a good deal of asphalt. These counties are in northeast Texas. Burnet county is in the southern central portion of the state.

These tar-springs, which yield a semi-fluid maltha, are often called oil or petroleum springs by those who do not understand the difference in the value of these different although in some respects similar substances.

In New Mexico, not far from Albuquerque, tar-springs are reported; also in Arizona and southern Utah; but the exact localities I have been unable to learn or verify.

In southern California, throughout the same region in which asphalt is found, maltha occurs in great abundance, oozing from springs on the hillsides and in the beds of water-courses in cañons, and after exposure to the elements becoming hardened into asphaltum. In consistence it passes by insensible gradations from a material scarcely to be distinguished from heavy petroleum to solid asphalt. It varies in specific gravity from 0.9906 to 1.100, the heavier material, though heavier than water, still remaining plastic like mortar. Springs near the old stage-road between

a Lesley, J. P., P. A. P. S., ix, 183; A. J. S. (2), xli, 139; H. Wurtz: Report, 1865; S. F. Peckham, A. J. S. (2), xlviii, 362, Nov., 1869; A. G. J., xi, 164.

b J. D. Whitney: *Geology of California*. Geology, I, 132; S. F. Peckham, A. J. S. (2), xlviii, 368.

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the Gaviota pass and the old mission of San Miguel (if my memory is correct) yield a quicksand cemented by maltha that oozes out and accumulates in great masses upon the side of the hill, becoming rigid as the maltha changes to asphalt. At Rincon point, about half way from Santa Barbara to San Buenaventura, a bed of sand overlying the shales, which there stand at a high angle, is saturated with maltha for about 20 feet in thickness over many hundreds of acres. The formation is exposed in the ocean bluff for at least a mile. Fig. 1 shows the manner in which the sand overlies the shale. (*a*)

Early in 1866, when trial-borings for petroleum were being conducted upon the San Francisco ranch, in the Santa Clara valley, Ventura county, maltha was found at a depth of 117 feet too dense to pump and without sufficient tenacity to admit of being drawn up with grappling hooks, yet sufficiently firm to clasp the tools and prevent further operations. On the plains northwest of Los Angeles an artesian boring that penetrated sandstones interstratified with shale to a depth of 460 feet yielded maltha.

In this region there are vast quantities of this material, which has not hitherto been found valuable, but which will no doubt at some future day be found useful in the arts. (*b*)

Maltha is also reported at the Shoshone springs, in Wyoming territory, and in cavities in the limestones of middle Tennessee. In the latter locality it occurs in small quantities, and has no commercial value.

STATES AND TERRITORIES IN WHICH LIQUID OR GASEOUS BITUMEN OCCURS.

NEW YORK.—In 1865 Jonathan Watson drilled a well in Ontario county, 5 miles east of Canandaigua lake, and found there a good oil-rock, plenty of gas, and a production of about 5 barrels of oil daily. A line drawn from this point west to lake Erie, and another south to the Pennsylvania line, would include all of the territory in the state of New York over which oil or gas has been obtained by boring (see map III), and along the shores of lake Erie, from the state line to Buffalo, at almost any point natural gas may be obtained from artesian borings. Fredonia, in Chautauqua county, a few miles south of Dunkirk, has been lighted by natural gas for more than forty years.

A great many wells have been bored along the lake shore and for some distance inland, and at a number of localities in Chautauqua and Erie counties they are reported to have produced small quantities of oil. In the southeastern portion of Chautauqua county, and that portion of Cattaraugus county north and west of Salamanca, the indications of a productive oil territory become more pronounced, but I have not been able to learn definitely that any wells in that region have yielded oil enough to pay their cost. The larger number of these wells were drilled many years ago, and detailed statements concerning their exact locality and the results afforded by them are now very difficult to obtain.

South and east of Salamanca the Bradford oil-field of Pennsylvania extends into New York, and has proved a very certain and valuable territory. The statements that are made in this report respecting the Bradford field apply equally to that portion lying in New York and in Pennsylvania. The field in New York lies south of the Allegheny river. (See map III.)

The next county east of Cattaraugus is Allegany, and at Cuba, in the southwestern part of that county, is the oil-spring described in 1833 by Professor Benjamin Silliman, sr. (*c*) Through the southern townships of this county the Richburg field has been recently opened with much promise. A few wells have been drilled in the southwestern part of Steuben county, but with what promise of commercial success has not yet been determined.

The wells in this region are from 1,600 to 2,000 feet in depth; the oil is of a dark amber color and of a specific gravity of 44° Baumé, very closely resembling that of the Bradford field.

PENNSYLVANIA.—A number of test wells have been drilled in the western part of Potter county, Pennsylvania, contiguous to Allegany county, New York, and some are reported to have yielded oil in small quantity, but most of them are understood to have been entirely unproductive.

The next county west is McKean county, and the greater portion of the Bradford field occupies that portion of the county embraced in about one-half the townships lying west and north of Smethport. As may be seen from the map (III) accompanying this report, the outline is irregular, with a small but detached portion lying to the southwest of the main body. This field has been developed since 1874, and while it has been very completely outlined by dry holes and wells of small production, there are many wells in different portions of the county outside the field that have yielded more or less oil. At Smethport a well yielded a "small quantity" of very dense amber-colored oil, while at Kane, in the southwestern part of the county, on the Pittsburgh and Erie railroad, is one of the most remarkable gas-wells on record. (*d*) The wells here are from 1,600 to 2,000 feet deep.

The next county west of McKean is Warren, and in it there are two well-defined productive fields of small extent. These are the Warren field, lying around the town of Warren, and the Clarendon and Stoneham field, lying to the south a short distance, yet entirely distinct from the former. These fields yield an amber oil of a specific gravity of 48° Baumé. The wells are from 800 to 1,100 feet deep.

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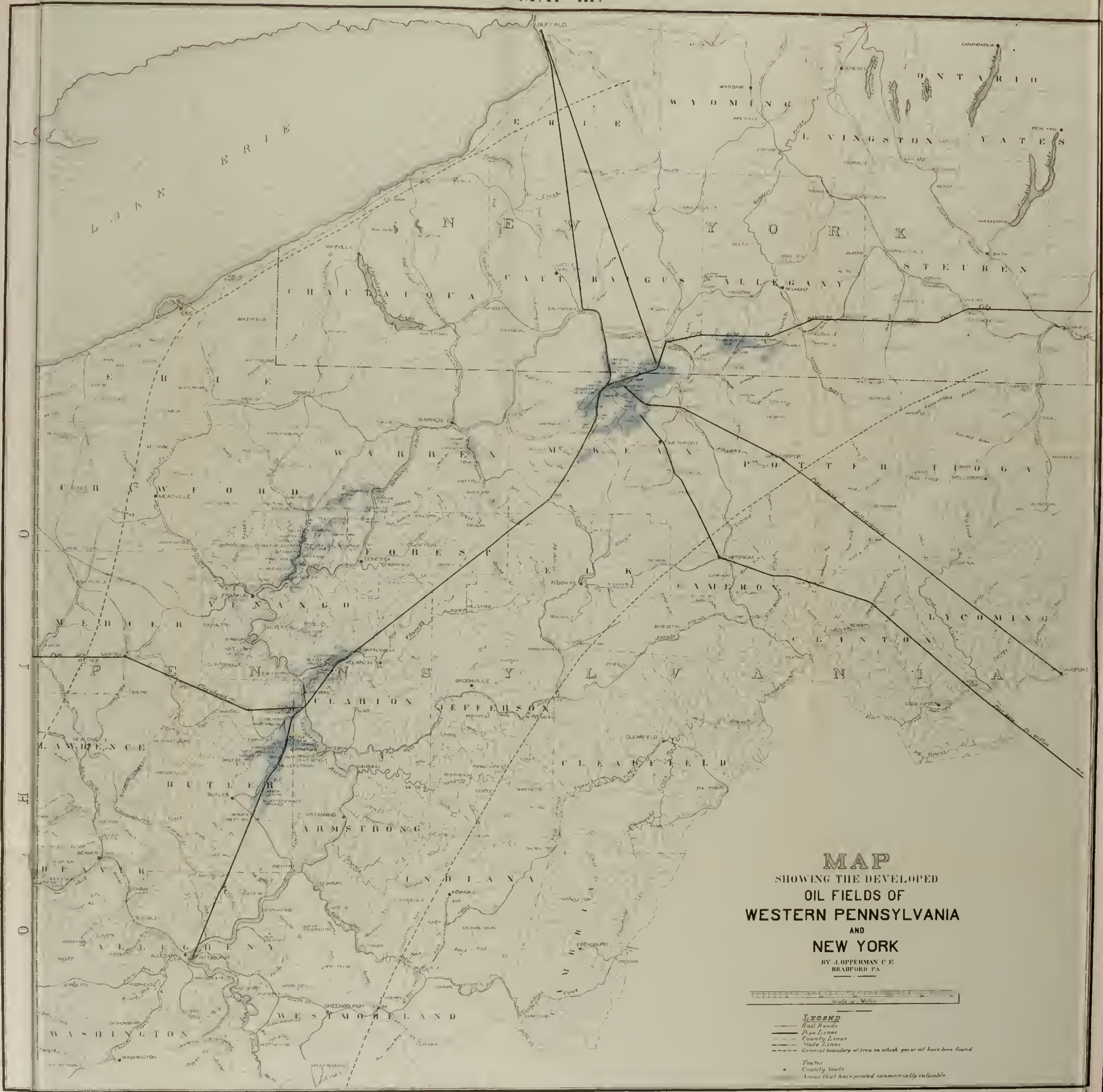
a *Report of Geological Survey of California:* Geology, II. Appendix, p. 51, Fig. 2.

b S. F. Peckham, A. J. S. (2), xlviii, 370; Am. C., iv, 6.

c A. J. S., (1) xxiii, 97.

d C. A. Ashburner, J. F. I., cviii, 347; P. A. P. S., xviii, 9, 419; T. A. I. M. E., 1879, 1878, 316; A. J. S. (3), xvi, 393, xvii, 69, xix, 168; J. F. Carll, P. A. P. S., xvi, 346.

MAP III.


MAP
SHOWING THE DEVELOPED
OIL FIELDS OF
WESTERN PENNSYLVANIA
AND
NEW YORK
BY J. OPPERMAN C. E.
BRADFORD PA.
Scale of Miles
LEGEND
Rail Roads
Pipe Lines
County Lines
State Lines
General boundary of Area in which gas or oil have been found
Towns
County Seats
Areas that have proved commercially valuable
LAKE ERIE
ONTARIO
OHIO
NEW YORK
PENNSYLVANIA
ERIE
CHAUTAUQUA
CATTARAUGUS
ALLEGANY
STEUBEN
WYOMING
LIVINGSTON
YATES
CRAWFORD
WARREN
McKEAN
POTTER
TIOGA
FOREST
ELK
CAMERON
LYCOMING
CLINTON
VENANGO
MERCER
CLARION
JEFFERSON
CLEARFIELD
LAWRENCE
BUTLER
ARMSTRONG
INDIANA
BEAVER
ALLEGHENY
WESTMORELAND
WASHINGTON
BUFFALO
ERIE
MEADVILLE
FRANKLIN
WARREN
BRADFORD
SMETHPORT
EMPORIUM
RIDGWAY
BROOKVILLE
CLEARFIELD
LOCK HAVEN
WILLIAMSPORT
WELLSBORO
BATH
CANANDAIGUA
PENN YAN
BUTLER
KITTANNING
INDIANA
EBENSBURG
GREENSBURGH
PITTSBURGH
WASHINGTON
BEAVER
CLARION
TIONESTA

In the central, southern, and southwestern portions of Warren county, from Tidioute, on the Allegheny river, southwest into Venango county, the territory known as Triumph hill was opened in 1868. Some wells were bored in 1860 by the Economites in the river opposite Tidioute, and later upon the high land on the south side of the river. But this territory is small. On the north and west side of the river (which makes a bend just below Tidioute) a narrow belt of territory that has been very productive extends across the hills into Venango county. Northwest of this belt, in the southwestern corner of the county, a small territory around Enterprise proved very productive. Other noted localities in this section are Fagundus, southeast of Tidioute, and New London and Colorado, southwest of the same place.

The wells in the Warren and Stoneham fields are in a horizon which lies in depth between the Bradford and Venango county fields. Those on the island in the Allegheny river, first drilled by the Economites in 1860, were 120 feet deep; on the hills they are from 560 to 570 feet deep. The oil produced here is dark green by reflected light and of the color of brandy by transmitted light, resembling in this respect the oil of the so-called Oil creek. At Sheffield, in the southeastern part of this county, is another remarkable gas-well.

Erie and Crawford counties lie west of Warren county, and have both been pretty well drilled over. At Erie, on the lake shore, a number of gas-wells has for many years furnished gas to dwellings and manufacturing establishments, and a few wells sunk 600 to 700 feet in the shale have yielded a few barrels of heavy green oil, suitable for lubricating machinery. The most successful of these wells (the Demming) did not, so far as I could learn, pay the cost of drilling. The oil has a specific gravity of 26° Baumé. At Union City, in the southeastern part of Erie county, wells have also been drilled in shale which yielded a small quantity of very dense oil for a very long time. The first well was drilled in 1859, soon after Drake struck oil, to a depth of 52 feet, and has yielded a small quantity of oil ever since. Several other wells have been drilled here, but none of them, so far as I could learn, have ever proved profitable.

Mr. J. P. Stranahan, of Union, informed me that he and his brothers dug out an oil spring thirty-five years ago at Oxbow hill, a few miles northeast of Union, and that it had flowed oil ever since. The boys set the gas from the spring on fire and boiled eggs in the flame.

In 1879 a well was drilled 2½ miles west of Union, that struck oil in "paying quantities" at 18 feet. In going deeper to get more oil the well was spoiled, and was afterward abandoned; but I conclude that at better prices Erie county can be made to produce a considerable amount of heavy oil. At Girard and other points near the lake shore gas-wells are productive.

Crawford county, excepting in the southeast corner, along the valley of Oil creek, has about the same record as Erie county. Along the valley of French creek and its tributaries, above and below Meadville, many wells have been bored, some of which produced oil, but none in quantities that proved remunerative.

Titusville is near the line of Venango county, in the southern part of Crawford county, and north of Titusville is Church run, a locality that for a time proved very productive. This neighborhood has yielded oil from the date of Drake's well (1859) up to the present time. Drake's well was 69½ feet deep, and penetrated only to the first stratum of sandstone yielding oil; but after the wells were drilled deeper a second and a third sandstone were reached, and a much greater yield was obtained. The valley of Oil creek has been drilled all over, and nearly everywhere south from Church run it has proved productive. The portion, however, that lies in Crawford county is comparatively small.

South of Crawford county lie Mercer and Venango counties. Mercer county has been well drilled over with test wells, particularly the eastern portion, but without developing any territory of value. Venango county has proved one of the four most productive counties in the state, and if complete statistics from 1859 were to be had it would probably head the list. Oil creek enters near the middle of its northern boundary and runs a little east of south until it enters the Allegheny river near the center of the county, at Oil City. The Allegheny river enters the county near the middle of its eastern boundary, receives Oil creek at Oil City, and, flowing southwest, receives French creek at Franklin, from which point it flows southeast, and leaves the county at its southeast corner. The valley of Oil creek, the triangle between that creek and the Allegheny river, and the region below Franklin, on the same river, is crossed at intervals by long and narrow belts of territory, often from an eighth to a quarter of a mile wide and several miles in length, which have produced and are still producing oil in enormous quantities. These belts occupy long troughs or depressions, level on their upper surface, and curved upward from the center on the under surface from side to side. In a few instances the productive territories have been found to resemble pools in their outline and dimensions, but the major portion of this whole county is crossed by a great number of these belts which have yielded enormously productive wells in the center and less productive ones on parallel lines along the sides, until at a distance in some instances of 20 rods on either side the drill failed to reveal the presence of either sand or oil. The oil of this section has been quite uniform in character, excepting that produced in the neighborhood of Franklin, a small territory in the angle formed by French creek and the Allegheny river. In color it is for the most part green, although a considerable quantity has been obtained that is decidedly black. The specific gravity has varied from 42° to 48° Baumé.

The Franklin district has furnished a lubricating oil of very superior quality from shallow wells. These wells are almost all in Cherrytree township, Venango county; but a few are in Franklin on the high bluffs south of the city.

Forest county lies east of Venango county. Here several belts extend from one into the other, and several independent areas of small extent have been developed within its limits. West Hickory, Foxburg, and Balltown have been the principal centers, but the county, on the whole, has not proved to be very important for oil production.

The next county east is Elk, but as an oil-field is of less importance than Forest. A few wells have been drilled in its northwest corner, and others in the neighborhood of Wilcox have produced oil; but the production, as a whole, is unimportant. Near Wilcox is a noted gas-well.

Jefferson county, lying south of both Elk and Forest, has received some attention, but is without reputation. I have not learned that any of the wells reported to have been drilled there have yielded oil; they certainly have not in valuable quantity.

A glance at map III, accompanying this report, will show a large belt of oil territory having a general northeast and southwest direction lying in Clarion, Armstrong, and Butler counties. This belt begins in the southwest corner of Clarion county, passes through the northern part of Armstrong county, and extends nearly to the center of Butler county. The wells are from 900 to 1,300 feet in depth, becoming deeper as they approach the southwest extremity of the belt. This belt has been exceedingly productive throughout its entire area, and furnished the bulk of the oil production of Pennsylvania from 1869 to 1877. Small areas in each of the three counties have been developed outside the principal belt that have yielded in the aggregate a large amount of oil, but their importance has been so overshadowed by the main Butler and Clarion fields that they have been but little noticed. At Petrolia, in Armstrong county, gas-wells have proved very productive, and at Leechburg, on the Kiskiminitas, this gas has been used for manufacturing iron.

In the lower part of Armstrong county petroleum was obtained in 1839 in salt-wells, and was used for derrick lights.

West of Butler county, in Lawrence county, many wells have been drilled, with varying success. In the southeast corner of this county, on Slippery Rock creek, a belt has been developed that has been moderately prolific; but outside of this small area the county may be said to possess but little value for oil purposes.

South of Lawrence county, in Beaver county, a very valuable field has been opened up in the neighborhood of Smith's Ferry, on the north side of the Ohio river. This territory is between 3 and 4 miles square, and the oil is uniformly different from that produced in other portions of Pennsylvania and the adjoining states of Ohio and West Virginia. Being of a light amber color, resembling pale sherry wine, though not transparent, and having a specific gravity of 50° Baumé, it will burn in a lamp in hot weather without refining. This oil is much more valuable than the average of Pennsylvania oils.

Allegheny county lies east of Beaver, and near its center is the city of Pittsburgh. Along the Allegheny river above Pittsburgh, particularly near Tarentum, in the northeast part of the county, petroleum has been observed for 40 or 50 years, and it was here that Mr. Kier obtained the first oil that he refined at Pittsburgh. This county has never been regarded as valuable for oil purposes.

Oil suitable for lubrication has been obtained at Greensburg, in Westmoreland county, and many wells have been drilled in Washington county; but the production of oil has been practically nothing. In the southeast corner of Greene county, which is the southwest county of the state, an area on Dunkard's creek has produced a few thousand barrels yearly for several years, but the territory is small, and has been comparatively unimportant.

Ohio and West Virginia.—There are three localities in Ohio that have yielded petroleum from an early date. These are the neighborhood of Mecca, in Trumbull county, the neighborhood of Belden, in Lorain county, and Washington county.

Mecca is near the center of Trumbull county, which lies directly west of Mercer county, Pennsylvania. The oil produced here is from shallow wells, less than 100 feet in depth, is of a specific gravity of 26° Baumé, and of very superior quality as a lubricator. The territory is about 4 miles in length, north and south, by 2½ miles wide, and lies upon the west bank of Mosquito creek, with the village of Power's Corners near its center. Large sums of money have been expended in boring for oil in the valley of the Cuyahoga, where there are numerous springs; but none of the wells proved profitable, although a small quantity of oil was obtained in nearly all of them.

The Belden district, in the southeast part of Lorain county, is of about the same dimensions (4 by 2½ miles), but lies with its longer axis east and west. Several varieties of oil are produced here from wells of different depths. The more dense is black, and has a specific gravity of from 26° to 28° Baumé, while the lighter is green, and has a specific gravity of from 28° to 36° Baumé. It is supposed that this territory is larger than present developments would indicate, as wells have produced oil at Liverpool and at Medina, in Medina county, both of which are several miles east and southeast of Belden.

In the southeast portion of Columbiana county, a short distance west of the Smith's Ferry district, in Pennsylvania, many wells have yielded in the aggregate quite a large quantity of petroleum, although, as compared with other localities, the yield is unimportant.

The Washington county district extends into Noble, Morgan, and Athens counties, and for the most part lies in the valley of the Muskingum and its tributaries. Petroleum was obtained here in brine wells as early as 1814, and was noticed by Dr. Hildreth, of Marietta, in 1833, and again in 1836. (*a*)

The white oak anticlinal, or so-called "oil-break" of West Virginia, extends from Newell's run, a tributary of the Little Muskingum river, in Newport township, Washington county, Ohio, to Roane county, West Virginia, passing through Pleasants, Ritchie, Wood, and Wirt counties, of the latter state, reaching its highest point at Sand Hill, where the axis crosses Walker's creek, the rocks here being raised about 1,500 feet above their normal level. The crest is about one mile wide from side to side (east to west), in which the rocks are practically level, the stratification being as uniform as in the rocks outside of the anticlinal; but along its axis it is not level, forming there undulations, in which the whole depth of the formation shares. This brings the entire series in three elevations: the first one north at Horse Neck, in Pleasants county; the second at White Oak, in Wood county; and the third at Burning Springs, in Ritchie county. Oil is found under these three elevations, and consequently there are in West Virginia three contiguous districts that yield oil. (*b*) A few wells have yielded oil at the northern extremity of the uplift on Newell's run, in Ohio.

The territory of "Cow run" is situated in Lawrence township, Washington county, Ohio, about 3 miles west of the northern extremity of the white oak anticlinal. Here the rocks for about three-quarters of a mile square are raised 350 feet above their normal level, dipping off gradually on all sides.

The Macksburg territory is of limited extent, and is situated in Aurelius township, in the extreme northern part of Washington county.

At Olive, in Noble county, where the brine well of 1814 was located, petroleum has been obtained, and also in the Scioto valley, but not in paying quantities. (See Map VI.)

At Blue Rock, southeast of Zanesville, in Muskingum county, Buck run, in Morgan county, and Federal creek, in Athens county, a few wells have proved profitable. At Rutland, near Pomeroy, in Meigs county, near Gallipolis, in Gallia county, and on Tug fork of the Big Sandy river, in Wayne county, West Virginia, oil-springs have been observed. These localities lie in an almost direct line from Blue Rock to Tug fork, and are supposed to indicate a line along which wells will ultimately prove profitable.

There are several horizons in this region lying at different depths that yield oil of different specific gravities. The facts relating to this subject will be elucidated in Chapter III. (*c*)

Along the lake shore, at Ashtabula, Painesville, Cleveland, Rocky river, and other localities, gas-wells have yielded profitable supplies for heating and lighting dwellings. (*d*) At Liverpool, Columbiana county, Ohio, and across the river, at New Cumberland, Hancock county, West Virginia, gas-wells have yielded very large amounts for a long time, (*e*) the gas from which is used for lighting dwellings and factories and for the manufacture of lampblack. In Knox county some of the most remarkable gas-wells on record have been discovered in boring for oil. This gas is also used for the manufacture of lampblack. A further description of these wells will be given in the chapter devoted to natural gas. (*f*) At Burning Springs, Ritchie county, West Virginia, the escape of natural gas was noticed by the earliest settlers. (*g*)

At the salines, in the valley of the Great Kanawha, above and below Charleston, petroleum has been observed for at least fifty years, and for a time the natural gas which arose with the brine in nearly all of the wells was largely used for evaporating purposes; but while the aggregate production of this locality has no doubt been many thousands of barrels, it was for the most part obtained before petroleum became an article of large demand, and much of it was doubtless wasted. (See Map VI.)

Kentucky and Tennessee.—The oil and burning springs that mark the line from Blue Rock, in Ohio, to the Tug fork of the Sandy river, in West Virginia, is continued in outcrops on Paint creek, Johnson county, Kentucky. This creek is a tributary of the west fork of the Big Sandy, and has been described by J. P. Lesley in his report published in 1865. (*h*) Springs are also met with near Saylersville, in Magoffin county. In Lincoln, Rockcastle, Pulaski, Casey, Green, Adair, Russell, and Metcalfe counties oil-springs are found, and oil-wells have been drilled at different times. Some of these wells in Lincoln and Casey counties are old salt-wells, drilled fifty or sixty years ago; others are oil-wells drilled during the excitement of 1865 and 1878. The oil sand in Lincoln county lies at a depth of about 300 feet. A number of wells have been drilled in this county in the neighborhood of Stanford, all of which are reported to have reached oil, but the wells have not been piped or pumped, and none of the oil has been put upon the market. In Wayne county the oldest well in the country is still flowing oil. It was drilled for brine on the little south fork of the Cumberland river, in the southeast corner of the county, in 1818. The oil is heavy, black lubricating oil. Wells have been drilled near Monticello since 1865 that yield a heavy oil of a dark-green color, specific gravity 25° Baumé, that has a high reputation as a lubricator. In Clinton county oil was obtained in 1866; in Cumberland county the old American well was bored for brine in 1829 and flowed oil till 1860; and in 1865 a large number of wells were drilled along the Cumberland river and the creeks flowing into it, and they probably gave the most

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a A. J. S. (1), xxiv, 63; xxix, 87.

b See sections, Plates III and IV.

c For many of the facts stated in this report respecting this region I am indebted to F. W. Minshall, esq., of Parkersburg, West Virginia.

d J. S. Newberry, Geo. Ohio, i, 161.

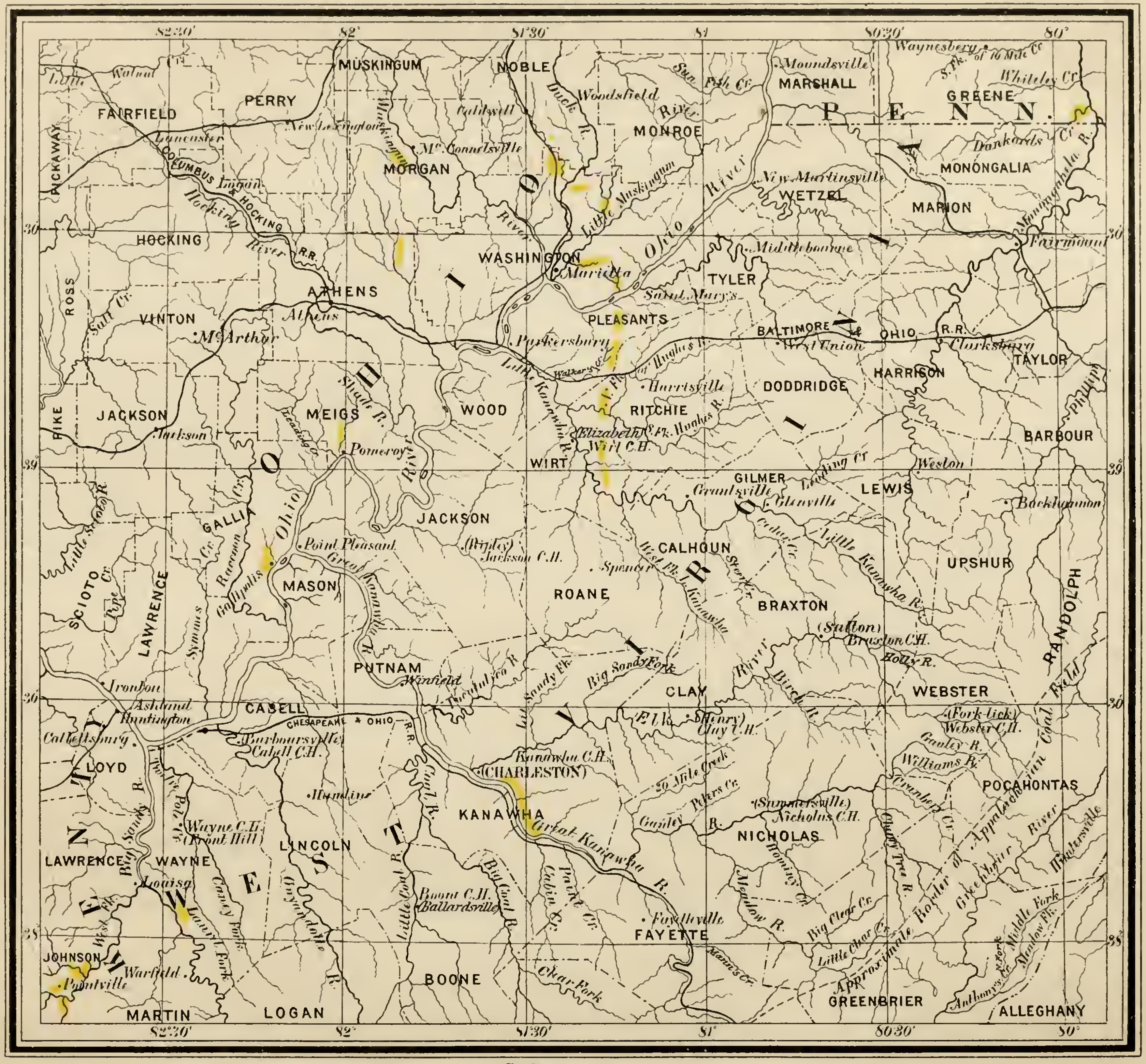
e *Ibid.*, iii, 118.

f Geo. Ohio, 44.

g S. P. Hildreth, A. J. S. (1), xxix, 87, 121.

h P. A. P. S., x, 33.

MAP VI.



Scale.

50 25 20 15 10 5 0 50 100 MILES. [STAT.]

certain and largest yield of oil that has ever been obtained for the same cost in any locality. At the same time, probably a larger proportion of the oil produced was wasted than has been the case anywhere else in the United States, as it is supposed that 50,000 barrels from the American well ran down the Cumberland river before any attempt was made to save it. The oil near Burkesville, Cumberland county, has a peculiar, offensive odor and a specific gravity of 37° Baumé. Amber oil of a lower specific gravity was obtained from other wells in small quantity, and a larger amount was yielded by wells on Oil fork of Bear creek (east of Burkesville), which was of a black color, with a specific gravity of 26° Baumé. The oil here appears to be in a sort of marble at 90, 190, and 380 feet from the surface.

On Boyd's creek, near Glasgow, Barren county, Kentucky, oil has been obtained for several years in commercial quantities, the wells being in the bed of the creek and on the adjoining hills. A few thousand barrels per year are obtained here. Wells have also reached oil on Beaver creek north of Glasgow. A well is also reported to have yielded "considerable quantities" of oil near Bowling Green, Warren county, and another near the Mammoth cave, in Edmonson county. (See Map V.)

Directly north of these counties, on the Ohio river, wells have reached oil at Brandensburg, in Meade county, at a depth of 900 feet; but those who drilled them afterward concluded that they were not deep enough. Three wells were also drilled near Cloverport, which yielded a small quantity of oil. Another well is reported in Bourbon county, and still another at Henderson, in Henderson county. This latter well is reported to have yielded a very valuable lubricating oil. Over at least one-third of the state scattering wells have yielded petroleum, some of which have been among the most remarkable in the country.

Springs of natural gas are common throughout the region just outlined; but I have not learned that the gas is anywhere used for any purpose, or that more than one well has ever been bored for gas, that at Bristow station, Warren county. Cumberland, Clinton, and Wayne counties, Kentucky, border Clay and Fentress counties, Tennessee, which, with Overton, Jackson, and Putnam counties, are drained by the east and west forks of Obey's river and other smaller tributaries, with Eagle and Spring creeks, all of which are tributaries of the Cumberland river. Many oil-springs are found in the valleys of these streams, and during 1867, 1868, and 1877 a number of wells were bored, almost uniformly producing oil, the larger part of which ran to waste for want of means of transportation. Trousdale, Macon, and Sumner counties, lying west of Jackson county and north of Nashville, also have oil-springs along some of their streams. To the west of Nashville about 40 miles another group of counties has oil-springs in the valleys of their streams, the principal field of operations being in Dickson county. Several wells drilled here from 1866–'69 to 1877 to a depth of between 400 and 600 feet yielded oil of a specific gravity of 44° Baumé.

In Hickman, Montgomery, and Maury counties there are springs, from one of which oil has been oozing since 1830, when it was opened by blasting for the foundation of a mill.

During the year 1863–'64 McMinnville, in Warren county, was the center of some activity in exploring for oil. A well sunk about forty years before for brine was sunk deeper for stronger brine. Oil flowed upon the creek, which took fire and destroyed the forests for 10 miles along its banks. Mr. M. C. Read visited this region in 1864, and found the agents of a Chicago company putting down five or six wells. These were located by witch-hazel men, at $500 each, to be paid when they struck oil. Mr. Read asserted that there were several bottomless pits of petroleum beneath an intensely hard, cherty limestone, very difficult to drill. The company spent the first assessment before they got through that stratum, when, the price of oil falling, they pulled out their tools and left. Cannon county, adjoining Warren county on the west, has been examined during the last season and many springs of heavy oil have been discovered. Oil has also been reported in a well near Chattanooga. The counties that I have enumerated cover about one-sixth the area of the state. (See Map V.)

ALABAMA.—Jonathan Watson, esq., of Titusville, Pennsylvania, drilled wells in northern Alabama in 1865 and got oil in two of them.

FLORIDA.—It is reported to me that there are no petroleum springs in Florida. A. A. Robinson, commissioner of the board of immigration, Tallahassee, Florida, in a letter, says:

> There is in the midst of an impenetrable cypress swamp near the coast, in Jefferson county, and about 35 miles southeast of Tallahassee, a mysterious column of black smoke, which has been rising for twenty years. At night it emits light, fitful and irregular, frequently lighting the sky so as to be seen miles away at sea. It is supposed to be a petroleum spring on fire. Much time, money, and enterprise has been expended to explore the swamp. No one has ever succeeded. It must be petroleum or a volcanic eruption. Some data may be found on the subject in the records of the United States coast survey.

MICHIGAN.—Oil and gas springs have been noticed on and near the shores of lake Huron and the entrance to the Saint Clair river. They are situated in several townships of Saint Clair county, not far from the city of Port Huron. A number of wells were bored near these springs in 1865, but none of the enterprises proved remunerative. (See Map VIII.)

ILLINOIS.—A well was bored at Chicago in 1865 that passed through strata that yielded petroleum both near the surface and at considerable depths. (*a*) The well was drilled for water. Recently a well has been reported as having been drilled in Montgomery county, a little north of east of Saint Louis, which yields a very heavy black oil, valuable as a lubricator.

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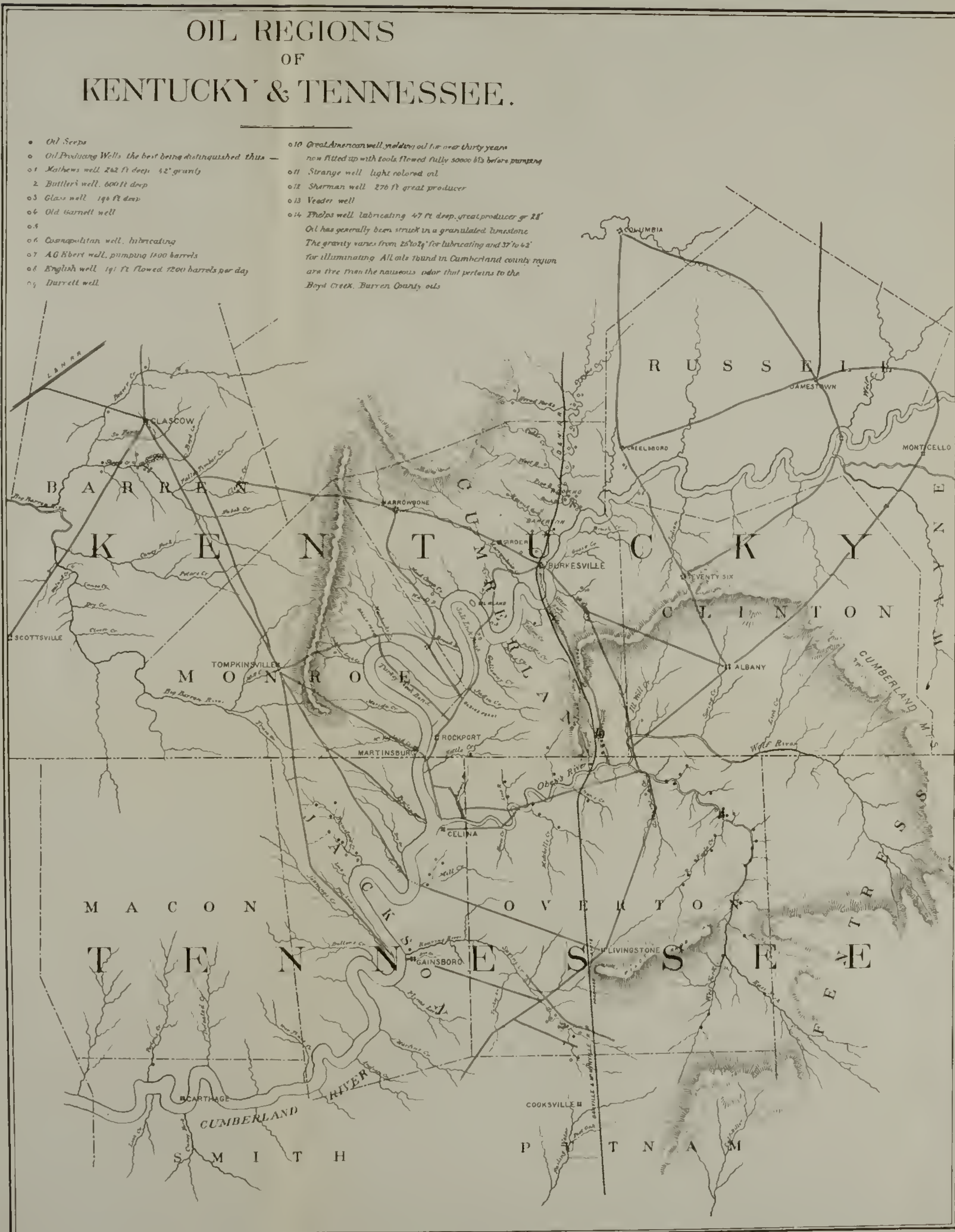
a A. J. S. (2), xl, 388.

MAP V.


OIL REGIONS
OF
KENTUCKY & TENNESSEE.
Oil Seeps
Oil Producing Wells the best being distinguished thus —
1 Mathews well 262 ft deep 42° gravity
2 Buttler's well. 600 ft deep
3 Glass well 190 ft deep
4 Old Garnett well
5
6 Cosmopolitan well. lubricating
7 A G Ebert well. pumping 1800 barrels
8 English well 191 ft flowed 1200 barrels per day
9 Darrell well
10 Great American well yielding oil for over thirty years now fitted up with tools flowed fully 50000 bls before pumping
11 Strange well light colored oil
12 Sherman well 276 ft great producer
13 Veeder well
14 Phelps well lubricating 47 ft deep. great producer gr 28°
Oil has generally been struck in a granulated limestone
The gravity varies from 25° to 29° for lubricating and 37° to 42° for illuminating. All oils found in Cumberland county region are free from the nauseous odor that pertains to the Boyd Creek. Barren County oils
L & N RR
GLASCOW
COLUMBIA
RUSSELL
JAMESTOWN
KEELSBORO
MONTICELLO
BARREN
ARROWBONE
CUMBERLAND
KENTUCKY
BURKESVILLE
SEVENTY SIX
CLINTON
SCOTTSVILLE
TOMPKINSVILLE
MONROE
ALBANY
CUMBERLAND MTS
ROCKPORT
MARTINSBURG
Wolf River
Obey's River
CELINA
JACKSON
MACON
OVERTON
TENNESSEE
LIVINGSTONE
GAINSBORO
FENTRESS
CARTHAGE
CUMBERLAND RIVER
COOKSVILLE
SMITH
PUTNAM

INDIANA.—Wells drilled for water at Terre Haute in 1870–'71 showed petroleum, and afterward a well drilled purposely for oil yielded 25 barrels a day of a heavy green oil. In Crawford county, "during the oil excitement" from 1864 to 1868, ten wells were bored, and almost every one yielded "a show" of oil; but in no case could a yield of more than a pint a day be heard of, and in some cases only a few oily drops upon the surface of thousands of barrels of water were found.

The oil-supply rocks of this vicinity are so limited that there is hardly a possibility of striking a paying well, and some of the white-sulphur fountains now running from wells bored for oil are more valuable than any oil-well possible in the county. More than 20 oil-springs have been noted in this county. (a) E. T. Cox, in the *Geological Survey of Indiana for* 1872, page 139, says:

During the great oil excitement of 1865–'66 quite a number of wells were drilled in the northern part of this (Perry) county, on the waters of Anderson and Oil creeks. These wells were generally carried to a depth of 700 feet, and in one or two of them was found a little oil and gas. Though it is extremely doubtful if oil in paying quantities can be found in the county, still I do not believe that these wells were carried to a sufficient depth to reach the corniferous and Niagara limestones, from whence the oil is obtained in the Terre Haute well.

Perry county joins Crawford county on its eastern border, and also contains oil-springs. In Lawrence county indications of petroleum have also been noted. Perry and Crawford counties, Indiana, are north of and opposite Breckinridge and Meade counties, Kentucky.

MISSOURI.—Some wells were drilled in this state about 1865–'68. A letter from Professor G. C. Swallow says:

A well was sunk on Mr. Boyd's land in Sec. 21, T. 33, R. 33, Barton county, 130 feet, without obtaining any considerable quantity of oil. Another well was sunk in Sec. 35, T. 34, R. 32, to the depth of 525 feet, principally in sandstone and shale; very little oil was found. In Barton and Bates counties oil often rises on the water of many springs in small quantities. In La Fayette county a well was sunk to a depth of some 600 feet through sandstone, shale, coal, and limestone. Very little oil was found, and none was saved. It appeared on the surface in a sandstone, and this led to the work upon the well. Another well was sunk in Ray county, from which small quantities were obtained. In Ray county oil often rises with the spring water and consolidates into asphaltum; in fact, there is no prospect of ever finding any oil in paying quantities in Missouri, though it comes to the surface in springs in hundreds of places in the region of the coal measures.

Ray and La Fayette counties are on either side of the Missouri river near the western boundary of the state; Bates and Barton counties are farther south, and are drained by the tributaries of the Osage river. Oil-springs are also reported in Cass county, north of Bates.

KANSAS.—Miami county, Kansas, is west of Bates county, Missouri, and is also drained by the tributaries of the Osage river. Oil and tar springs abound in this county, and oil was obtained in the salt-wells at Osawatomie, Paola, and other places. In 1860 a well was bored 275 feet deep on Sec. 15, T. 17, R. 23, and "they got oil all the way down". It is supposed it would yield one barrel a day. Another well was bored in 1865 on Sec. 11, T. 17, R. 24. Oil-springs are also reported in Linn county. The oils are all black and heavy, and are fit only for lubrication. (b)

LOUISIANA—In the low lands bordering on the Calcasieu and Sabine rivers there are numerous springs of petroleum. (c) (See Map VII.)

NEBRASKA.—In a communication to S. F. Peckham from Professor Samuel Aughey appears the following:

No petroleum springs, as such, are known in Nebraska. No wells have been drilled purposely for oil. In boring for coal at Ponca, Dixon county, a small amount of oil rose to the surface from a depth of 370 feet. I obtained only about a spoonful by saturating woolen cloths. Don't amount to anything. The same traces of oil have been obtained this season in boring for coal at Decatur, Burt county. I have observed genuine petroleum floating in the north Platte river above the mouth of Willow creek, in extreme western Nebraska. Thus far I have failed in my efforts to trace it to its source.

Dixon and Burt counties are on the west bank of the Missouri river, in northeast Nebraska.

MONTANA, WYOMING, DAKOTA, COLORADO, AND NEW MEXICO.—A letter addressed to the director of the United States geological survey, July 6, 1881, in which inquiries were made regarding the occurrence of petroleum in the territories, was referred to the different geologists in charge of those regions, and in reference to those named above S. F. Emmons replied as follows:

Certain horizons of the cretaceous sandstones in the Rocky mountain region are more or less impregnated with hydrocarbons, and when sufficiently and systematically examined will be very likely, in favored localities, to yield merchantable petroleum in considerable amount, if the conditions are such as to make it pay. As yet, however, but little has been done, and the returns of my experts, who were instructed to report on any petroleum wells that they could hear of, contain no schedules on this industry. The only information I can give you, therefore, is of the most general description. * * * Actual springs of petroleum I have not seen, though I have occasionally heard of a little oil on the surface of water. Considerable thickness of sandstones was observed by me on the southern slopes of the Uinta mountains, notably in Ashley creek basin, which were black with carbonaceous matter. The weathered surfaces, however, had lost all of their volatile ingredients, and doubtless suffered thereby some chemical change; so that it was more of an asphaltic material that was left. In the neighborhood of Bear River City, on the Union Pacific railroad, near the boundary of Utah and Wyoming, and also about 15 miles east of there, in the hills, wells were sunk, from which a few barrels of petroleum were obtained, but I fancy it never proved a pecuniary success. The supply was small, and the product of too little value to pay for working. This was nine or ten years since.

I heard of a man who claimed to have a petroleum well somewhere between the south end of the Wind river and the Big Horn mountains from which he was obtaining an excellent lubricating oil, and which he sold at a high price. Some excitement was spoken of in the papers a year or two since about petroleum on the west slopes of the Black hills of Dakota; and there has been talk of some out on the hills to the

a *Geological Survey of Indiana*, 1878, p. 520.

b *Report of Geological Survey of Miami county, Kansas*, by G. C. Swallow. 1865. Kansas City, Missouri.

c Professor William M. Carpenter, A. J. S. (1), xxxv, 345.

MAP VII.

MAP
Showing BITUMEN SPRINGS
in
TEXAS AND LOUISIANA
Legend.
Oil Springs.
Oil Wells.
Rail-Roads.
TEXAS
LOUISIANA
GULF OF MEXICO
SCALE

MAP VIII.


MAP
Showing OIL REGIONS
of
MICHIGAN AND CANADA
Legend
Oil Wells.
Oil Springs.
Rail-Roads.
Scale
LAKE HURON
LAKE ERIE
LAKE ST CLAIR
BRUCE
ESSEX
TUSCOLA
Bad Axe
Bay City
Saginaw
Flint
Lapeer
Lexington
Sarnia
Petrolia
London
St Thomas
Chatham
Windsor
Amherstburg
Ann Arbor
Pontiac
Monroe
Goderich
Clinton
Exeter

northeast of the same, though I hear nothing of them lately. All these points would strike the same cretaceous rocks, but are too far away from lines of communication to encourage capital to develop at present. Within the past year some coal company "struck oil" in a well on their property a few miles south of Cañon City.

In brief, then, as far as I know, there is no actual production of petroleum in my district; it exists, however, in the cretaceous rocks which extend over the greater part of it along the eastern slope of the Rocky mountains from British Columbia to Mexico and in many of the interior valleys. Blake's map, published in the Ninth Census, will give you a rough general idea of the extent of this formation. Whether the petroleum thus existing can be made to pay, whether it is concentrated in sufficient quantity, or is of good enough quality, can only be satisfactorily proved by practical experiment. I think myself it will probably do so in time, locally, at any rate; but, owing to low price, it may be some years yet before labor and other conditions favor the development.

An artesian well at Yankton, Yankton county, Dakota, 300 feet deep, is reported to have struck blue shale which is saturated with petroleum.

Returns have been made to the Census Office from two parties in Wyoming. The first is located 75 miles north of Point of Rocks station, on the Union Pacific railroad, and south of the Shoshone Indian reservation, in Sweetwater county. This property is reported to consist of ten or twelve springs and a well 60 feet deep. The oil is very heavy—19° Baumé. The second locality is southwest of the Black hills, in Laramie county, near the Dakota line, 25 miles northwest of the junction of the east and west forks of Beaver creek. This property consists of springs of water, from the surface of which the oil is collected and strained, and supplies a local market.

CALIFORNIA.—Bitumen is distributed very generally throughout the coast ranges from San Francisco bay south to Los Angeles county, and petroleum is reported to have been obtained in a well on Tunitas creek, San Mateo county. The extensive operations of the Pacific Coast Oil Company are reported to be located in Lexington township, Santa Clara county, but I have been unable to learn any particulars in reference to the production of their wells. Tar-springs are found through Monterey, San Luis Obispo, Santa Barbara, Ventura, and Los Angeles counties. In the Santa Clara valley, in Ventura county, and in the hills on both sides of it, much money has been expended during the last seventeen years, and some oil has been obtained, the principal localities having been in the cañons of the Sulphur mountain that border the Ojai ranch on the south, at the mouth of the Sespé cañon, further east, and both east and west of Petrolia, near the upper end of the valley; but it is impossible at this distance to express an opinion respecting the real value of the operations or the product obtained. The opinion that I expressed in 1866, in a report that I at that time submitted to Professor J. D. Whitney, then state geologist, I believe has been justified in every particular, so far as the Santa Clara valley is concerned.

In the *Report of the Geological Survey of California* (Geology, II), appendix, page 73, it appears as follows:

The expectation of extraordinary results, that will admit of comparison with those that have been produced in Pennsylvania, must be set aside. The expectation of a fair return and a permanently profitable investment may be reasonably entertained; and the application of capital on this basis to this interest will make it of great importance to the state, and especially to that particular section in which the bituminous outcrops occur.

SECTION 2.—GEOGRAPHICAL DISTRIBUTION OF BITUMEN IN FOREIGN COUNTRIES.

The notices of bitumen in foreign countries do not admit of very exact classification, as the name petroleum has been from early times applied indiscriminately to nearly every form of bitumen by writers but little acquainted with the subject.

BRITISH AMERICA.—Bituminous minerals, often solid when they appear upon the surface, but more frequently semi-fluid or fluid, occur at many localities in British America. Petroleum has been almost without exception obtained by boring.

Bituminous schists, called petroleum schists, have been observed on the banks of the Mackenzie river; (*a*) also near fort McLeod, 260 miles north of fort Benton, Montana, and at another point 36 miles southwest of the same point, near the 114th meridian, on the Taylor farm. (*b*) In the valley of the Elk river that empties into Athabaska lake "there is a peaty bog, whose crevices are filled with petroleum, a mineral that exists in great abundance in this district. We never observed it flowing from the limestone, but always above it, and generally agglutinating the beds of sand into a kind of pitchy sandstone. Sometimes fragments of this stone contain so much petroleum as to float down the stream". (*c*) The occurrence of petroleum or bitumen on the Athabaska was recorded by Sir Alexander Mackenzie in 1789, and again by Sir John Richardson in 1851. The first-named author states, on page 87 of his narrative, alluding to the forks of the Athabaska or Elk river, that "at about 24 miles from the forks are some bituminous fountains, into which a pole 20 feet long can be inserted without the least resistance. The bitumen is in a fluid state; heated, it emits a smell like that of sea coal". Sir John Richardson says: "The whole country for many miles is so full of bitumen that it flows readily into a pit dug a few feet below the surface."

On the Abittibi river, south of Hudson's bay, petroleum is reported, occurring in strata resembling those just mentioned (*d*)

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a E. Heibert, B. G. S. F. (3), iii, 87.

b J. C. Nelson, of the Dominion surveyor-general's office.

c Account of the route to be pursued by the Arctic Land Expedition in search of Captain Ross, by Captain Back, R. N., *Jour. Roy. Geog. Soc.*, iii, 65, 1833.

d *Descriptive Catalogue of the Minerals of Canada at the Philadelphia Exhibition*, page 63.

A number of localities are mentioned where petroleum occurs in Newfoundland, among them West bay, Port-au-Port bay, Piccadilly, and a point between Bonne bay and Saint John's island, to the north of Cow harbor. (*a*) At lake Ainslee, on Cape Breton island, petroleum springs occur, and a number of borings have been made without success. At Kempt, Nova Scotia, limestone occurs, in which petroleum is found of a honey-yellow color in small cavities which are lined with crystals of calcite. (*b*) Petroleum is also reported at Hillsborough, New Brunswick. Here also occurred the deposit of albertite which for a number of years, like the grahamite of West Virginia, was very famous. It is of eruptive origin, filling a vertical fissure in shale. It was at first extensively used for the production of coal-oils before the introduction of petroleum, and afterward, like grahamite, for enriching gas coals. The deposit is practically worked out and the mine is abandoned.

Petroleum springs were first mentioned at Gaspé, near the entrance to the gulf of Saint Lawrence on the south, in 1844, by Sir W. E. Logan. They have since been noticed in successive reports of the Canadian geological survey, and were in 1865 made the subject of a special report by Dr. T. S. Hunt, in which he mentions a number of localities in the neighborhood of Tar Point, Douglastown, and other places in the neighborhood of Gaspé bay, along a line of 20 miles, where the rocks are impregnated with solid, semi-solid, and liquid bitumens, which ooze from them at many points. Several wells were drilled here, but in none of these localities do the springs yield any large quantities of oil, nor have the borings which have been made in two places been as yet successful. (*c*)

In reply to inquiries made in June, 1881, Dr. A. R. C. Selwyn, director of the geological survey of Canada, says:

As regards Gaspé and Cape Breton, the question is easy. Petroleum has been found, but never in sufficient quantity to be commercially available.

Wells were drilled near Wequamikong, Great Manitoulin island, in lake Huron, in 1865, and oil was obtained, but not in remunerative quantities.

The productive oil-fields of Canada lie in the county of Lamberton, in the western part of the province of Ontario, and principally in the township of Enniskillen, around the village of Petrolia. In the *Descriptive Catalogue of the Minerals of Canada at the Philadelphia Exhibition*, page 61, appears the following:

The whole oil-producing region around Petrolia has an area of about 11 square miles, with its longest diameter running about north-northwest. The bluish clay of the surface has a pretty uniform depth of about 100 feet, and beneath it borings penetrate an average thickness of 380 feet of interstratified bluish-gray dolomites, shales, and marls (the last being locally known as "soapstone") to the most productive stratum, or 480 feet in all. At first many of the wells both at Oil Springs and Petrolia flowed spontaneously, but now they all require to be pumped. The oil is accompanied by sulphurous saline water, and has an offensive odor. The difficulty in getting rid of this odor at first stood much in the way of the successful competition of the Canadian petroleum with mineral oils from other countries; but since the refineries have been able to thoroughly accomplish this, it has been acknowledged to be a very superior burning oil

Theo. D. Rand, J. F. I., LXXX, 59, says:

In 1861 numerous wells were sunk, many through the surface clay only, others one or two hundred feet in the rock, and oil was everywhere obtained in fair quantity. During the winter of 1861–'62 and the following spring the great flowing wells which have made this region so famous were struck one after another. The yield from these wells was enormous, ranging by estimate from 1,000 to 7,000 barrels a day.

MEXICO.—A vein resembling albertite is reported in the state of Guerrero, 170 miles from the city of Mexico, and petroleum of a beautiful light-straw color and a density of 32½° Baumé is reported from near the city of Mexico. (*d*) It is also reported from laguna Tampamachoco, on the north side of the Tuxpan river, on the gulf of Mexico, 20 miles from Tuxpan. Tar-springs are reported to rise in the gulf of Tampico, and their products float ashore.

About 20 miles from the bar of the river Coatzacoalcos, that rises on the isthmus of Tehuantepec and empties into the bay of Campeche, and half a mile inland, the "laguna del Alquitran", or lake of Tar, is thus described:

It is surrounded by tall grass, and measures upward of an acre in extent. The exterior crust is a compact layer, sufficiently solid to enable one to walk around its border; but the center is soft, and under the rays of a vertical sun the surface shines like polished jet. In many places there are diminutive ponds of water tinged with iridescent colors, while in others the fluid bitumen bubbles up as if in a constant state of ebullition. Sometimes these bubbles are aggregated so as to form small cones three and four feet high, which evolve vapors, burst, and overflow. As a proof that the petroleum springs of the isthmus are subterraneously connected, I may mention that whenever an ebullition or a spontaneous conflagration occurs in the lake of Tar it is at the same time repeated in all the others, although widely separated. At rare intervals, about once a year, the lake of Tar is spontaneously ignited, and the whole surface is covered with a sheet of flame, which is accompanied by volumes of dense smoke, impregnating the air with powerful bituminous odors. On the day of our visit one of these spontaneous conflagrations took place, and continued to burn until after sunset. The heat arising from the flames was very great, and the sky was darkened by clouds of black smoke that arose above the lake, recalling the descriptions given of the Caspian "field of fire". I learned that within a league and a half, in a southeasterly direction from the right bank of the Coachapa, a tributary of the Coatzacoalcos, there are six smaller lakes, clustered together within a space of 300 acres. (*e*)

Other localities less remarkable were visited in the vicinity, and immense quantities of asphaltum are said to occur along the shores of the Gulf of Mexico above and below the mouth of the river.

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a *Geological Survey of Canada*, 1877–'78, c. 24; John Milne, F. R. S., J. G. S. L., xxx, 738.
b D. Honeyman, A. J. S. (3), i, 386.
c *Geol. Canada*, 1862, pp. 788, 789.
d Am. C., ii, 290.
e *Report on Petroleum in Mexico*, by John McLeod Murphy, 1865.

THE WEST INDIES.—In 1837 Professor R. C. Taylor described a vein of solid bitumen that occurs at Casualidad, three leagues east of Havana, Cuba. He describes the mass as a wedge-shaped vein "filled with carbonaceous matter, as if injected from below". He calls the substance coal, but shows that it is very unlike ordinary coal, both in its specific characteristics and in the mode of its occurrence, and says:

In whatever way we may account for the origin of this remarkable coal deposit, we must be led to view it in some measure in connection with the petroleum which is found in the rocks of this region. The petroleum springs which rise from fissures in the Serpentine at Guanabacoa have been known for two centuries. Nearly contemporaneously with the discovery of the coal of Casualidad, it has been observed about midway between the cities of Matanzas and Havana, not far from the sea-coast. (*a*)

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The strike of the Casualidad vein is nearly north and south, conforming to the local range of stratification, although the general range is east and west, following the general direction of the island. At the outcrop the vein is scarcely a foot thick, but at the depth of 30 feet it is enlarged to 9 feet, descending nearly vertically. Other positions in the neighborhood of the principal mine of this substance show its prevalence in the country. We have examined and reported upon some excavations two leagues from Havana, on the road to Tapozte. (*b*)

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Even in the bay of Havana the shore abounds with asphalt and bituminous shales in sufficient quantity for the paying of vessels, as a substitute for tar. It is stated that in buccaneering times signals used to be made by firing masses of this chapapote, whose dense columns of smoke could be recognized at great distances. It is matter of history that Havana was originally named by the early settlers "Carine"; "for there we careened our ships, and we pitched them with the natural tar, which we found lying in abundance upon the shores of this beautiful bay." Petroleum leaks out in numberless places in this delightful island from amid the fissures of the Serpentine, and perhaps has deeply-seated sources. We are acquainted with abundant springs of petroleum between Holquin and Mayari in the eastern part of the island, and we possess notices of others in the direction of Santiago de Cuba. In fact, the entire chain of the West India and Windward islands present similar phenomena of petroleum springs. (*c*)

The reputation of Cuba asphaltum, or chapapote, is too well known to require comment, as it is exported from the island both to the United States and to Europe. Petroleum has never been found there in such quantities as to be commercially important.

Petroleum was reported as occurring in San Domingo by William M. Gabb, esq., who made a geological reconnaissance of the island in 1872. It occurs about three miles from Azua, in the southwestern part of the Dominican republic, on a stream called El Agua Hediondo, or Stinking Water. An unsuccessful attempt was made to bore here in 1865–'66. The product of the springs is a thick maltha, of a density of 22½° Baumé = 0.945, which does not yield paraffine. (*d*)

The petroleum of Barbadoes was described in 1750 by Griffith Hughes, in a work entitled *Natural History of the Island of Barbadoes.* He says:

The most remarkable fossils of bituminous kind is green tar. It is obtained by digging holes or a trench, and it rises on the water. It issues from hills, and is gathered in the months of January, February, and March, and serves to burn in lamps. Munjack is dug out of veins. It is stated that one of these veins was fired by a negro, who built a fire on a hillside to roast potatoes, and it continued to burn for five years.

The heavy, dark-green or black petroleum was an article of commerce, under the title "Barbadoes tar", for many years prior to the introduction of petroleum for illuminating purposes.

The Pitch lake of Trinidad is the most extensive known deposit of asphaltum. It was described by Dr. Nugent in 1811, (*e*) by G. P. Wall, esq., in 1860, (*f*) and by Professor T. Rupert Jones in 1866. (*g*) The lake is about three miles in circumference, and is described as a mass of asphaltum, sloping to the northern sea-coast. Although firm enough to bear a team of horses, it is still somewhat plastic, and appears to be in motion toward several points that act as vortices, as the trunks of trees disappear and after a time emerge at some distance from the point at which they sunk. Small lakes and streams of water abounding in fish are described as distributed over the surface, with numerous islands covered with tropical verdure. The asphaltum is exported from the island to the United States and Europe, where it is used for the preparation of roofing materials and in the preparation of mastic pavements. It does not yield paraffine on distillation, and has not, therefore, been proved valuable in the arts for the purposes to which albertite, grahamite, and other similar substances are applied. In 1857–'58 an attempt was made to manufacture illuminating and other oils from the pitch, and Mr. William Atwood spent more than a year there superintending operations on the island; but that and all other attempts to use the material for such purposes have failed. It is, however, applied to other uses in the arts in enormous quantities, and the supply appears to be practically inexhaustible.

"South of cape de la Brea is a submarine volcano, which occasionally boils up and discharges a quantity of petroleum. Another occurs on the east side of the island, which throws up on the shore masses of bitumen." (*h*)

SOUTH AMERICA.—Humboldt mentions in his personal narrative the occurrence of petroleum springs in the bay of Cumana, where the oily fluid rises and spreads upon the surface of the sea. (*i*) Wall mentions the occurrence of asphaltum in the province of Maturin, on the mainland opposite Trinidad, and observes that other districts of the Llanos are generally affirmed to furnish it, although he did not examine them. (*j*) On the northern shores of the United States of Colombia and along the Magdalena river asphaltum is reported in immense quantities.

a *Philosophical Magazine*, x, 161–167.
b Taylor's *Statistics of Coal*, p. 578.
c *Ibid.*, page 579.
d E. Waller, Am. C., ii, 220.
e T. G. S. (1), i, 63.
f Q. J. G. S., xvi, 467.
g *Ibid.*, xxii, 592.
h Taylor's *Statistics of Coal*, p. 584.
i *Travels*, Bohn's ed., i, 198; iii, 113.
j Q. J. G. S., xvi, 467.

Under date of August 10, 1880, Commercial Agent Plumacher, of Maracaibo, gives a very elaborate description of the petroleum deposits of Venezuela, from which I infer that the slopes of the Cordilleras that inclose the lake of Maracaibo abound in asphaltum, maltha, and petroleum. It is difficult, however, for one locally unacquainted to eliminate reliable details from the report.

Petroleum is reported in Ecuador at Santa Elena, along the sea-shore, and Henry, in his *Early and Later History of Petroleum*, page 144, says:

Pits from 10 to 12 feet deep are dug into the sand till clay is reached, and, when the oil which oozes from all sides has filled them, it is dipped out. Near the wells are primitive furnaces, built with sun-dried clay, on which are open iron boilers. The bituminous matter is thrown into these vases and cooked until all the volatile products disappear and leave a thick pitch.

A well-known region in northern Peru near Payta, on the Pacific coast, is undoubtedly very rich in petroleum. The existence of this material was known in Peru before the conquest, as a mummy of date prior to that event in the Peabody Museum of Archæology of Harvard University has been prepared with it. The pitch was also used for coating earthenware on the inside, particularly liquor jars.

Several wells have been bored here, one of which produced several hundred barrels daily, and it is claimed by those who are conducting the operations that flowing wells may be obtained with great certainty over an area many miles in extent. A refinery has been built at Callao, but the recent war between Peru and Chili has caused a suspension of operations. The Peruvian oil does not yield any paraffine, nor a considerable amount of naphtha.

It is reported that in Bolivia the three principal springs of Cuaruzute, Plata, and Piguirainda form an oil stream 7 feet wide. (*a*) This wonderful story lacks confirmation.

ENGLAND.—In reply to a letter of inquiry in relation to the occurrence of petroleum in England, E. W. Binney, F. R. S., the distinguished geologist, wrote, November 14, 1881, as follows:

I am in receipt of yours, wherein you ask me if petroleum has been found in quantity in Great Britain. It was found about one hundred years since in making the Duke of Bridgewater's tunnel at Worsley, at Wigan and West Leigh in the Lancashire coal-fields, at Coalbrookdale and Wellington in Shropshire, and Riddings in Derbyshire, two other coal-fields; also in a peat bog at Down Holland, near Ormskirk, in Lancashire, but none to my knowledge in commercial quantities. The greatest supply that I have ever seen has not been more than 50 gallons a day, and even that soon diminished. When I went down Mr. Oakes' pit at Riddings in 1848 the petroleum came out of the black shale roof dripping, and not as a spring. The coal is a gas-coal in the lower part of the middle coal measures.

In a paper read before the Manchester Geological Society, March 30, 1843, Mr. Binney, in company with Mr. John Hawkshead Talbot, described the manner in which the petroleum occurred at Down Holland moss, northwest of Liverpool, on the north bank of the Mersey, near its mouth:

The whole of the moss is in cultivation either under the plow or in grass, and has been so for at least forty or fifty years, and all or the greater portion of it lies at a lower level than the high-water mark of the sea at Formby. On approaching the place where the peat containing petroleum occurs, from Down Holland, the authors soon became aware of its presence by an empyreumatic smell, resembling that yielded by Persian naphtha, and the water in the ditches was also coated with a thin film of an oily, iridescent fluid that floated upon its surface. In walking over some oat-stubble fields, and thrusting their heels through the black decomposed peat forming the soil, they felt a hard, pitchy mass, of 3 or 4 inches in thickness, which yields no smell unless it is burnt. On exposure to the atmosphere for a time the pitchy matter lost the greater part of its inflammability, and was finally converted into black mold. This substance also occurred under the roots of the grass in old sward fields, but it then yielded an odor similar to the petroleum that floated on the surface of the water, and pervaded the moist peat. (*b*)

I remember to have once met a lady who spent her childhood in New Hampshire, where she recollected a peat bog presenting similar phenomena to that above described.

Arthur Aiken, esq., in 1811, described the occurrence of petroleum in the great coal-field of Shropshire. He says the thirty-first and thirty-second strata are coarse-grained sandstone, entirely penetrated by petroleum; they are both together 15½ feet thick, and have a bed of sandy slate clay about 4 feet thick interposed between them. These strata are interesting as furnishing the supply of petroleum that issues from the tar-spring at Coalport. (*c*) In 1836 it was still further described by Dr. Preistwich, who says:

The well-known tar-spring at Coalport, which had its rise in one of the thick sandstones of the central series, formerly yielded nearly 1,000 gallons a week, but it now produces only a few gallons in the same time. In sinking a shaft at Priorslee the 20-yard rock was so charged with petroleum that the shaft was converted into a tar-well. It formerly yielded 2 or 3 gallons a day. In a pit at the top of the same dingle petroleum exudes in so great abundance from every crevice in the "little coal", and from the shale forming the roof, that the colliers are obliged in the latter case to have large plates of iron suspended over them. More rarely petroleum is found in cavities of the Pennystone nodules. (*d*)

Dr. Richard Bright described in 1811 a liassic limestone in the neighborhood of Bristol, containing "claws of crustaceæ, corallines, and millions of the stalks of encrinites. They were first noticed by Mr. Miller surrounding calcareous concretions in the black rock, which are penetrated with petroleum. Petroleum sometimes exudes from the rock in small quantity". (*e*) A correspondent of *Iron* describes, in 1875, the occurrence of petroleum in a coal

a *Deutsche Industrie Zeitung*, 1868, p. 400.
b Papers read before the Manchester Geological Society in 1842–'43, p. 17.
c T. G. S. (1), i, 195.
d T. G. S. (2), v, 438.
e T. G. S. (1), ii, 199.

pit at Longton, in North Staffordshire, the first discovery being made in a seam of coal that seemed to be saturated with it. Five or six tons a week are collected : a valuable addition to the output of coal. The coal is used for the manufacture of illuminating gas, and is rich in hydrocarbons. (*a*)

France and Switzerland.—There are three sections of France from which bitumen is reported. Petroleum floats on the water of springs, and the rocks in the neighborhood are saturated with bitumen at Saint-Boëz, Basse Pyrénées; (*b*) it has not been found anywhere, however, in the Pyrenees in quantities commercially valuable. In the hills that skirt the highlands of Auvergne, at Gabian, near Béziers, petroleum is reported. At Ardèche and Autun asphalt occurs, and in the neighborhood of Alais and at Bastenne asphaltic limestones are obtained and used in large quantities in the preparation of the asphaltic pavement so largely used in Paris and other French cities. (*c*) The third district is in Savoy, and extends into Switzerland. In the Val de Travers the celebrated bituminous limestones of Pyrmont and Seyssel occur in the department of Ain. This asphaltic stone is not stratified, but is crossed with fissures in all directions, and consists of cretaceous limestone, calcareous schists, and molass, the latter a sort of asphaltic breccia. The porous limestones are saturated with bitumen, and the siliceous pebbles and fragments of the molass are cemented with the same material, as has been repeatedly proved on comparison. The limestone is quarried and pulverized and is then heated, and while hot it is thoroughly mixed with asphalt extracted from the molass by repeated boiling in water. This asphalt rises to the surface of the water and is skimmed off. The mastic thus prepared is used in enormous quantities in Paris and other French cities. A similar material is reported from the Tyrol, in eastern Switzerland.

Germany.—In Alsace, on the lower Rhine, at Schwabweiler, Pechelbronn, and Lobsan, petroleum has been obtained for many years and has been employed for local uses, but it has never been introduced into commerce. Several wells have been drilled at different points, and a small yield of oil has been obtained in some of them, but the enterprises, on the whole, were not remunerative. Petroleum is also reported near Carlsruhe, in the grand duchy of Baden, but concerning it I have no particulars. In Hanover, on the Lüneburger heath, south of Hamburg and east of Bremen, the occurrence of petroleum has been known for at least a century. Since 1863 several attempts have been made to procure petroleum near Oberg by boring, and at different times, particularly within the last two years, the reports have been such as to encourage an expectation of a production rivaling that of Pennsylvania.

In 1876 it was stated that at Oberg the source of the petroleum was supposed to lie at a depth of 700 or 800 feet, and that it had been obtained at Edemissen and Oedessen by the re-establishment of mines having but a single shaft. In Kline Eidessen the sand is permeated with petroleum to such an extent that it is found on the water that collects in foot-tracks. At the village of Weitze, in the northern part of the district, is found an extensive stratum of sand of about 1,000 meters long, 600 meters broad, and 75 meters deep, which corresponds to 45,000,000 cubic meters, the upper strata of earth containing about 10 per cent. of petroleum. The owner of this tract, which has been penetrated to 125 feet, has often bored and obtained petroleum in a very primitive way through the gushing of oil from the sand. (*d*)

In March, 1880, a company was organized in Bremen for the purpose of deep boring, with the expectation of obtaining at greater depths than had hitherto been penetrated a lighter variety of oil, that previously obtained from wells 220 feet deep having had a specific gravity of 28°, and commenced operations on the southern border of the Lüneberger heath, at a point 25 miles east of Hanover, on the railroad to Brunswick. A refinery has been established at Peine, 20 miles from Hanover, and a pipe-line, has been laid from the wells.

Mr. William C. Fox, United States consul at Brunswick, reports that traces of petroleum have been found in belts or spots commencing in the village of Klein Schoppenstate, in the duchy of Brunswick, and running west in a direct line for 40 miles to the village of Wietze, on the river Aller, a navigable tributary of the Weser. Two of these belts are at present known: the Oelheim, near Peine, and another 8 or 10 miles to the northwest. The former contains about 25,000 acres, and embraces the villages of Edemissen, Odessa, Windesse, and Steterdorf.

At present, borings are confined to about 20 acres, and there are 12 pumping wells, yielding 1,250 barrels a week. A flowing well, struck last July, caused great excitement, the petroleum having a specific gravity of 0.888, and producing, when refined, about 40 per cent. of illuminating oil of very superior quality, 40 per cent. of lubricating oil, and 5 per cent of naphtha. (*e*) For barreling, American barrels are preferred. While this field may be said to be one of the most promising fields, it cannot be said yet to promise any considerable competition with the fields of Pennsylvania.

Denmark and Sweden.—At Hölle, near Heide, in Ditmarschen, over an immense bed of petroleum, there is a layer of light diluvial sand 20 feet deep, saturated with tar, which may be cut like cheese. There is also found here an important bed of asphaltic limestone, similar to that of Seyssel. (*f*)

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a San Fran. Min. and Sci. Press, xxi, 184.
b M Thoré, L'année Sci. et Ind., 1872, p. 251.
c S. P. Pratt, Q. J. G. S., ii, 80.
d Archiv für Pharmacie, ccix, 461.
e Report, October, 1881.
f Dr. L. Meyn, J. S. A., xxi, 12.

At Nullaberg, in the northwestern district of Wermland, west Sweden, metamorphic strata of gneiss and mica-schist have been observed. Bituminous matter is distributed everywhere throughout the whole mass of these strata, so as to be present even in the smallest fragment, giving them a black color closely resembling gunpowder. (*a*)

ITALY.—Petroleum wells have been dug and bored along the southern borders of the valley of the Po, in the provinces of Voghera, Piacenza, Parma, Modena, and others, and in the provinces of Chieti, east of Rome, on the Adriatic sea, and of Caserta, on the gulf of Tarentum. Small quantities of petroleum have been obtained in these localities for centuries; also in the province of Girgenti, on the island of Sicily. Asphalt occurs at Marsiconnova and in the valley of Pescara, and asphaltic schists or bituminous clay have been observed in many places in southern Italy.

Professor Silvestri described, in 1877, paraffines and homologous hydrocarbons, which he obtained in lava about 13½ miles on a direct line from the great central cone of Etna. (*b*) The gas-springs of the Apennines have been many times noticed as of scientific interest, but have never been made of economic value.

The petroleum interests of Italy have been for many years locally valuable, but do not promise to become of greater importance.

DALMATIA AND ALBANIA.—On the island of Brazzo, on the coast of Dalmatia, and also at Ragusa, on the mainland south of Brazzo, extensive deposits of asphaltum are reported. This island is nearly opposite the valley of Pescara, on the Italian coast.

Farther down the coast of the Adriatic lies the island of Zante, where a petroleum spring occurs in a marsh near Chieri that was mentioned by Herodotus in the fifth century before Christ. One well was drilled 300 English feet, and produced about half a hogshead daily, which progressively diminished; another was drilled later that at the same depth struck a black, hard, and fetid limestone; and another was at the side of the marsh, and struck oil at 70 feet, yielding 5,000 liters in seven hours. The latter afterward became completely sterile, and was abandoned, and borings made near the spring in 1865 were not successful. (*c*) On the mainland east of Zante lies the coast of Albania. There, in the neighborhood of Selenitza, occur some of the most extensive and remarkable asphalt deposits in Europe. Strabo remarks that "in the country of the Apolloniates there is a place called Nymphæum. It is a rock which emits fire, at the foot of which flows a spring of warm bitumen, which probably proceeds from liquefied bitumen, because on a neighboring hill there is a mine of bitumen, where, as related by Posidonius, the earth, from the excavations from which the bitumen has been exhausted, converts itself into that substance". (*d*)

Vetruvius also mentions the same springs, and says: "Around Dyrrachium and around Apollonia are springs which emit great quantities of pitch with water." (*e*) Durazzo, in Albania, occupies the site of the ancient Dyrrachium, and the convent of Pollina is built upon the ruins of Apollonia, both of which are found near the emboucheur of the Vojutza (Aous of the ancients), about six hours to the northeast of Avlona. "It appears that the curious phenomena which these springs manifest to-day arrested the attention of the Greek and Roman naturalists, because they are mentioned in the works of Aristotle, Pliny, Ælian, and Dion Cassius." (*f*) Setting aside some erroneous ideas, due to the ignorance of the ancients regarding natural phenomena, recent studies of the bituminous deposits of Epirus confirm in a remarkable manner the observations made by these early writers, and the testimony of more modern authors is less abundant and exact than that furnished by the ancient historians. Recently the bitumen from this section has been employed in Trieste, Naples, and Marseilles as a substitute for rosin in calking ships.

Between Durazzo and Avlona the coast of Epirus is level, and consists of plains formed by the alluvium of the rivers Usoli Komobin (Senussus of the ancients), Beratino (Apsus), and Vojutza (Aous), which drain Albania throughout its length, and which have their sources in the high mountains of Macedonia. It is in the hills at the foot of these precipitous and almost inaccessible mountains that the deposits of asphalt occur in great variety of detail. M. Coquand, to whose elaborate article I am mainly indebted for the facts here stated, (*g*) regards the exploitation as very rude and of very great antiquity, probably extending from a period long prior to the Christian era to the present time, but destitute of any general system. This want of method, while compromising the future interests of the deposit, has opened it up at many points, and has admirably exhibited the manner in which the mineral lies in the formation. It is easy to perceive that it does not lie in regular beds or veins, but in irregular masses in the midst of sandstones and conglomerates, of the form of which no general description will give an idea, except that a sort of parallelism may be observed among them, and that each mass consists essentially of a central portion of considerable thickness, which gradually thins out in all directions to zero. In no case does the bitumen penetrate the roof above the mass, but was evidently injected from below. The following illustration (Fig. 2) shows at a glance a deposit that has furnished an enormous quantity of bitumen. A depth of 3 meters (9.84 feet) is not rare

a L. J. Englestrom: *The Geological Magazine*, iv, 160.

b Gazetta Chemica Italiana, vii, 1; B. D. C. G., 1877, 293; C. N., xxxv, 156.

c *Les Mondes*, October, 1865.

d B. S. G. F., xxv, 20. Translated from French rendering.

e *Ibid.*

f This passage and the others given above can be found in the original in *Bul. Soc. Géo. de France*, xxv, 20.

g B. S. G. F., xxv, 20.

MAP I.

Map showing the Distribution of Bitumen throughout the World.

in the thickest places. The bitumen is almost always of very great purity, and generally consists of compact, very homogeneous masses, very black, brilliant, tarnished upon the surface, very friable, with a resinous fracture, softening by percussion or heat, and with a pronounced asphaltic odor.

The ancient workings have caved in, making their exploration no longer possible. It appears, to judge by tradition, and, above all, from the ancient workings, now overgrown with oaks many centuries old, that the exploitation reaches back to a time anterior to Strabo; because we read in that author that, following Posidonius, the bituminous earth, which he calls *ampelites*, was a remedy against the worms that eat the vines, the worms by this means being destroyed before they had ascended the trunk to the young sprouts. This method appears to have been practiced until lately, and perhaps it is to-day, because the greater part of the bitumen of Albania was exported to Smyrna, where it was used for the preservation of vines, and more frequently for the calking of ships.

Some of the springs of water rising from the formation containing the bitumen of Albania are accompanied with maltha, but in insignificant quantity.

Roumania.—The Roumanian oil-fields lie in the northeast part of Wallachia and the southern part of Moldavia, in the valleys of the streams that drain the eastern slopes of the Siebenbürgen.

The Wallachian oil district lies on the southern slopes of the Transylvanian Alps, and is more extensive than that of Moldavia. The wells are from 6 to 12 miles north of Plojeschti, a station on the Roumanian railroad. In Bakoin the inhabitants use the inflammable gas which issues from the ground to cook their meals. The manner of obtaining the oil is very primitive, the wells being dug as for water, the landlord receiving a tenth of the net produce as rent. A part of the crude petroleum is refined at Sarati and Plojeschti, and part is sent by rail to Vienna, Pesth, and Odessa.

The Moldavian petroleum fields occupy a triangle bounded by the rivers Taslen and Trotusch, not far from Adschud station, on the Roumanian railroad. The wells near Morneschti do not exceed 120 meters (394 feet); those near Salante and Comonesti 50 to 70 meters (164 feet to 230 feet) in depth. Like the Wallachian wells, they are worked in the most primitive manner, and the proprietors here receive as rent one-third of the gross produce. The cost of the petroleum at the well's mouth does not exceed 4 francs per 100 kilograms (20 cents per 220 pounds).

The Moldavian petroleum is darker than that of Galicia, and remains fluid at a temperature of 20° Celsius—4° F.[a]

Galicia.—Petroleum is found in many localities on the Hungarian side of the Carpathians, but its exploitation is of little or no importance. In Galicia there are three principal localities that yield petroleum and ozokerite: the region around Sandecer, in west Galicia; that around Bobrka, near Dukla, in middle Galicia; and that around Boryslaw, in east Galicia, and Basco, on the confines of Moldavia. This region is said to be in general outline 400 miles long by 40 miles wide. Although ozokerite is found associated with petroleum wherever it occurs in both Galicia and Roumania, its production is principally confined to the east Galician district, in the neighborhood of Boryslaw and Stanislow. It appears from statistics that I have met with that the fields of east Galicia were at first much the most important; but while the total production of Galicia has decreased, the relative production of west Galicia has increased. The exploitation has been conducted in a very rude manner, largely by Polish Jews, who occupy that country, and all attempts at innovation by the introduction of machinery, both for boring and for refining, have been resisted with great pertinacity.

The development of oil territory by shafts has been encouraged by the amount of ozokerite that almost everywhere accompanies the oil and that cannot be obtained by other methods of exploitation. Wells have been bored, however, which in some instances have been productive and in many others have failed. The great importance of the ozokerite industry, which will be referred to in detail in a subsequent chapter, will prevent the complete substitution of borings for shafts.

Russia.—Petroleum is reported to have been observed in northern Russia, in the province of Archangel, on a streamlet that runs into the river Betchora; also at "some distance from Orenburg", on the Ural river, but the exact locality was not given.

In official reports the Russian petroleum fields are divided as follows:

Government of Tiflis.—Mirsanski, Schirorski, Eldarski.

Government of Baku.—Bakinski, Derbentski, Kaitags-Tabarsaranski.

Kuban district.—Kadygenski, Kudako.

Terek district.—Gronenski, Maïsha-Kajevski, Karabulakaki, Brajimavski, Benojevski.

Daghestan.—Berikaki, Djernikentaki, Naflutanski, Bashlinski, Tupsu-Kutanski, Ghiak-Salgav, Kukinski, Napkutanski.

A reference to map I will show that these districts are embraced in a triangle, the apex of which is at the mouth of the Kouban river, near the entrance to the sea of Azof, extending eastward to the Caspian sea, and embracing that portion of its western coast lying between the mouths of the rivers Terek and Kura, and embraces the flanks of the Caucasus and the valleys of the principal rivers that drain them. There are also indications of petroleum across the Crimea that have attracted some attention.

The Kouban oil-fields proper begin at Taman, situated on the strait which connects the Black sea with the sea of Azof, and extends along the foot-hills of the western extremity of the Caucasus mountains to the river Balah, a distance of about 250 miles.

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a Dr. H. E. Ginth, *Oester. Monatschrift f. d. Orient*, 1878; John Fretwell, jr., J. S. A., xxvi, 481.

The Apscheron oil-field as at present worked lies within a radius of 20 miles of the city of Baku; but the larger portion of the oil has been obtained at Balachany, 12 miles north of Baku, where naphtha has been produced from the most ancient times, and from Sabonutchi, which was explored in 1873. This first part contains (1880) forty-seven wells, of which twenty-eight are productive, yielding 6,192,000 pounds daily of an average specific gravity of 0.8675, while the second part yields 6,622,000 pounds per day of the specific gravity of from 0.820 to 0.860. The specific gravity is very variable in the same well, and in general diminishes with the depth, being greatest near the surface, from loss of gas. The light oil contains volatile products of a specific gravity of 0.62, of which no use is made. The illuminating oil varies from 15 to 85 per cent., the average being between 35 and 40 per cent. (*a*) On the outskirts of the field a colorless oil is obtained that can be burned without refining. This oil soon thickens and becomes asphalt.

The oil seems to lie in a sort of quicksand, irregularly interstratified with clay, as fine, loose sand rises with the oil and collects around the wells so that it has to be shoveled away. This oil has been known to spout from an 8-inch hole from 50 to 60 feet high; yet there is no regular stratum of sand yielding the oil, and no particular depth at which it may be struck. One well in the Kouban yielded oil of 46° at from 8 to 10 feet in depth. This oil does not contain paraffine.

The Bebeabat field is below Baku on the coast of the Caspian sea, and produces oil resembling that of Baku; but it deteriorates by keeping, and is often run up on a salt lake near by and set on fire. On the island of Tchillekin, or Naphtha island, on the eastern shore of the Caspian sea, a well was drilled which produced a small quantity of oil of a better quality than that of Baku, and one well at about 140 feet yielded oil, and at 200 feet yielded hot water. Ozokerite and "living earth", which is a mixture of soft asphalt and pulverized shells, abounds along this shore. (*b*)

The Caspian sea is dotted with numerous islands, which produce yearly a large quantity of naphtha (petroleum), and it has been no uncommon occurrence for fires to break out in the works and burn for many days before they could be extinguished. In July, 1869, owing to some subterranean disturbances, enormous quantities of petroleum were projected from the wells and spread over the entire surface of the water, and, becoming ignited, notwithstanding every precaution, converted the sea into the semblance of a gigantic flaming punch-bowl many thousands of square miles in extent; but the fire burnt itself out in about forty-eight hours, leaving the surface of the water strewed with the dead bodies of innumerable fishes. Herodotus mentions a tradition that the same phenomenon was once before observed by the tribes inhabiting the shores of the Caspian sea.

There is practically no limit to the amount of oil to be obtained at Baku, but with the exception of the Caucaso-Carpathian region the petroleum production of Europe is only of local importance. The production of maltha is insignificant, but the deposits of asphaltum and asphaltic limestone are of great and increasing importance. No region except the Caucasus has made any approach to rivalry in European markets with the petroleum products of the United States.

ASIA MINOR.—Many of the localities furnishing bitumen in Asia are extremely difficult to locate with exactness; but gas-springs are said to occur on the coast of Karamania, (*c*) which is that portion of Asia Minor bordering the northeast portion of the Mediterranean sea. Bitumen is also reported in Armenia near lake Baikal, and in southern Siberia near Derabund; (*d*) asphaltum near Iskardo (*e*) and near Cashmere; petroleum in Assam (*f*) and Pegu; (*g*) also near Kohat. (*h*) Gas-springs accompanying mud volcanoes are also reported in Kerman. (*i*) The authorities for these localities are nearly all to be found in works published in India, to which I have not had access.

"The asphalt of the Dead sea and its vicinity has been noticed by Strabo and other ancient writers, and many conjectures have been made by both ancient and modern authors respecting its origin. It seems to be a well-established fact that the asphalt rises in such large masses during or after earthquakes as to remind one of islands floating on the sea. While this asphalt, having a density of 1.1040, floats on the water of the Dead sea, which has a density of 1.1162, it would sink in the water of the ocean. The rocks in the neighborhood of the sea are often bituminous cretaceous limestones, containing a large quantity of asphaltic material. This is particularly to be observed in several of the ravines that border it, where the dolomitic limestones are highly charged with bitumen, and, being broken up and carried down into the sea by the winter torrents, the bitumen becomes disengaged, and is cast upon the shore." (*j*)

In one of these ravines, on the eastern borders of the sea, M. Lartet describes pebbles of silex cemented into a pudding-stone by bitumen and stalactites of asphalt produced by the liquid bitumen slowly dripping from the bituminous cretaceous limestones. This, too, is washed into the sea and cast on shore. The amount received by the sea in this manner, however, is not sufficient to account for the islands of bitumen seen floating on the surfact. (*k*)

On the western border of the valley of the Jordan similar deposits occur at the same level, and in many localities throughout Judea and Arabia Petræa from immemorial periods asphalt and maltha (slime) have been obtained from springs and shallow pits.

a M. Goulichambaroff, *Jour. Rus. Phys. and Chem. Soc.*, xii, 5; *Nature*, xxiii, 42.
b Communication from J. R. Adams, of Oil City, Pennsylvania to S. F. Peckham.
c Beaufort: *Survey of the Coast of Karamania*, 1820.
d G. T. Vigne: *Rock Oil, near Derabund*, Kabul 1842.
e G. T. Vigne: *Travels in Kashmir and Little Thibet*, 1842.
f Report Geo. Surv. of India, I, pt. 2, p. 55.
g Lt. Duff: Pegu oil gas. *Jour. As. Soc. Bengal*, 1861.
h E. Thornton: Oil-spring near Kohat, *Gazetteer of India*, 1862.
i H. Pottinger: *Petroleum of Kerman*, 1840.
j Lartet, B. S. G. F., xxiv, 12.
k *Ibid.*

Deposits of bitumen have been described as occurring near Zaho, in Kurdistan, 440 miles above Bagdad, on the Tigris. From the description I should conclude that this material is asphaltum. It was used successfully in 1874–'75 on the steamer Mosul for making steam, and also for the manufacture of gas. Several other outcrops of bitumen occur nearer Bagdad, and liquid petroleum occurs at many points upon the road from Ribamieh to Bagdad, and also between Bagdad and Mosul, in the valley of the Tigris. (*a*)

Persia.—Persia abounds in bitumen springs, which have been noticed and described by travelers and historians from Herodotus to the present time. One of the most noted springs of water yielding bitumen is situated five German miles from Suza, at Ardericca. Others are located on the plateau of Iran, near Durr, in the valley of of Jerabi, and also at Chusistan, not far from a volcano that was active in the second century. The bitumen wells Kerkuk or Tuzkurmati, four days' march southward from Arbela, are also celebrated. They may be known at a great distance through their odor, their sulphur vapor producing headache, on which account they are unendurable in summer time. Other localities of minor importance in the mountains that separate Persia from Kurdistan and the valley of the Tigris are mentioned. The naphtha springs of Van Kalesi were inclosed in the walls of a castle, where they flowed from a niche. Another castle is described as belonging to Sassanite times, situated upon a crag above a naphtha spring that was arched over with great blocks of freestone—perhaps from very ancient times.

Bitumen in its various forms has been used in the valley of the Euphrates and adjoining regions from the earliest times. (*b*)

Hindostan.—Natural gas furnishes the material burned in a number of Hindoo temples in Thibet and northern India. Petroleum wells are reported in Cashmere and Thibet, but I have been unable to learn anything concerning their exact localities. A locality occurs in the Punjab that has attracted some attention, but it has not yet been proved to be of importance. It lies in the corner between Cashmere and Cabul, and is nearly 100 miles by 90 in extent, being mostly between the Indus and Jhelum, in what is called the Sind Sagur Doab (two rivers), and is mainly in the mountainous or hilly part (Kohistan) of the Doab. The oil-springs are in the northern slopes of the Salt range that lie upon the southern border of this region, or in the Choor hills that lie upon its northern border. Oil, maltha, and asphaltum occur at these springs. Borings have been made at Gunda, and yielded at first 50 gallons a day, which gradually decreased. This oil is dark-green in color, is of a specific gravity of 25° Baumé, and has been used by the natives for burning with a simple wick, resting on the side of an open dish. (*c*)

Burmah.—In a letter from Rev. J. N. Cushing, dated Toungoo, September 14, 1881, appears the following in relation to the wells in this country:

> There are only two places in all Burmah where petroleum is produced to any extent, viz: Arracan and Yenangyoung, in upper Burmah. The production of the wells in Arracan is very small. Within a few years a company has been formed to work them as an experiment, but I have never seen any statement of the results, and think they must be inconsiderable. Yenangyoung (Earth-oil river) is a large town on the Irrawaddy about 400 miles north of Rangoon, and the oil-wells lie about 3 miles east of the town, among some low and very barren hills, the chief vegetation of the unproductive soil being several varieties of cactus. There seemed to be a good deal of light, soft, sandstone, through which here and there ran layers of a dark rock resembling granite. The roads were in some places worn into the hills to a depth of 10 feet, the fierce torrents formed during the rain washing out all loose soil.
>
> When I visited the wells they were about 200 in number, although some were not yielding oil. These were upon ground as highly elevated as any, and occupied an area of about 100 acres. They were of various depths, the deepest being about 160 cubits (240 feet). I do not think that the number of wells has greatly increased since my visit, for before that petroleum had been found only in that locality, although search had been made for it in adjacent localities. What might be found by the skilled labor of the far West using the scientific knowledge which gives it success I do not dare to say.

China.—There do not appear to be any wells in China that are made for the purpose of procuring petroleum; but from the communications made by M. Imbert to the French Academy, and also by L'Abbé Huc, it appears that petroleum is obtained in wells bored for salt, as it often is in this country, and that the oil is often accompanied by inflammable gas. The Chinese call the latter Ho-tsing (fire-wells), and use the gas for a variety of purposes, such as boiling brine and for domestic fuel, the gas being conveyed long distances in bamboo tubes, terminating in a clay or porcelain burner. In his *Travels in the Chinese Empire*, chapter vii, L'Abbé Huc says:

> When a salt-well has been dug to the depth of a thousand feet, a bituminous oil is found in it that burns in water. Sometimes as many as four or five jars of 100 pounds each are collected in a day. This oil is very fœtid, but it is made use of to light the sheds in which are the wells and caldrons of salt. The mandarins, by order of the prince, sometimes buy thousands of jars of it, in order to calcine rocks under water that render navigation perilous.

Specimens of this petroleum sent to France were submitted to a committee of the French Academy for examination. (*d*)

The wells are described by L'Abbé Huc as occurring in the province of Sse-tchouen, which is the largest province of China, and borders upon Thibet. Petroleum is also reported from the northern province of Shansi.

a L. Mongel: *Ann. des Mines* (7), vii, 85; Proc. Inst. of Civil Engineers, 1875, p. 307.

b *Ritter's Erdkunde*, ix, 147, 177, 519, 555; xi, 191; x, 142.

c B. S. Lyman, Trans. Am. Phil. Soc., xv, 1.

d *Comptes-Rendus*, xxii, 667.

JAPAN.—The petroleum fields of Japan lie in the southern part of Yesso and the northwestern part of Niphon, and have already been noticed in chapter I, page 17.

JAVA.—Mineral oils are found in many of the islands of the Indian archipelago, and are there known under the name of Minjak Lantoeng at Java, or Minjak Linji at Sumatra; and as they are much used by the natives, they are regularly collected and sold in the markets of the principal villages and towns. The localities where these oils rise spontaneously in natural fissures or artificial excavations are ordinarily surrounded by warm or saline mineral springs.

A specimen of oil from Palantoengan, in the residency of Samarang, has the consistency of tar and a density of 0.955 at 16° C. A specimen from Tjiakijana, in the district of Porbolingo, in the residency of Banjoemas, is as liquid as water, with a deep green color by reflection, and has a density of 0.804 at 16° C. Spontaneous evaporation produces a mass of the consistency of yellow butter; distillation yields 40 per cent. of paraffine. (*a*)

Von Baumhauer, the distinguished chemist, examined and reported upon six specimens of petroleum from as many different localities in the Dutch East Indies: from Amönchay, in Borneo; Bodjoinegoro, in Rembang; Madjalengka, in Cheribon; in Soerabaga; Lematang-Ilir, in Palembang, Sumatra; and Iliran and Banjoesin. His examination shows that the petroleums of Rembang and Cheribon are of very excellent quality, while the others are of a viscous consistency. He remarks that petroleum in this region is very abundant, and is easily obtained at a depth of 250 meters (820 feet), and recommends boring, considering the oil as of great importance to the country. (*b*).

AUSTRALIA.—Petroleum is reported as occurring in Australia and New South Wales, and crude paraffine near Gisborne, in New Zealand.

AFRICA.—Petroleum is reported from Egypt, as examined by Frederick Weil, with a density of 0.953, but on distillation it did not yield naphtha or illuminating oil with a density of 0.800. It was considered a superior lubricator, and is especially adapted to heating marine boilers and in the manufacture of gas. (*c*) It is also reported as having been discovered in Algeria, in the Dahra-oraisaic, the region occupied by the tribe of Beni-Zarouel, in that part of the chain that overlooks the plain of Chiliff. A spring of glutinous petroleum here indicates a suitable place for exploitation, the product having the ordinary properties of maltha. (*d*) A more complete examination of Africa will doubtless reveal other localities which yield bitumen.

An examination of map I will show that bitumen occurs on the American continent along a line extending from Point Gaspé, in Canada, to Nashville, Tennessee, and in Europe-Asia along a line extending from Hanover, on the North sea, through Galicia, the Caucasus, and the Punjab. These are the principal lines. In America it also occurs on the Pacific coast from the bay of San Francisco to San Diego; again from northern Nebraska to the mouth of the Sabine river, on the Gulf of Mexico; again from Havana near the western end of Cuba, through San Domingo and the circle of the Leeward and Windward islands, to Trinidad; thence westward on the mainland to the Magdalena river, and southward from that point to cape Blanco, in Peru. In Europe-Asia bitumen occurs on the lower Rhine and in the valley of the Rhone; from northern Italy, following the Apennines, to southern Sicily; along the eastern shores of the Adriatic, through Dalmatia and Albania, into Epirus; again along the depression in which lies the Jordan and the Dead sea; again along the mountains that border the valley of the Tigris in the east; again from western China through Burmah, Pegu, Assam, Sumatra, and Java; and lastly in Japan. It will be observed that these lines are for the most part intimately connected with the principal mountain chains of the world.

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a Bleekrode, Rep. de Chem. Appl.; C. N., v, 158; *Le Technologiste*, xxiii, 402.

b Arch. Neerland, iv, 299; Mon. Sci., 1870, p. 53; W. B., 1878.

c Mon. Sci. 1877, p. 295.

d *Les Mondes*, xxxvi, 318.

CHAPTER III.—THE GEOLOGICAL OCCURRENCE OF BITUMENS.

SECTION I.—GENERAL CONSIDERATIONS.

The relation of geology to the occurrence of bitumens has been very liberally discussed during the last half century. In attempting to review the literature of this subject one is impressed with the fact that for the most part the opinions expressed may be said to be *provincial*, inasmuch as they are based on observations made over a comparatively limited area, and from these limited observations generalizations are often made to include all of the varied conditions under which bitumen occurs in different parts of the world. My intention has been to compile this chapter from the papers of professional geologists who have directed their attention to the subject, and it is while attempting this work that the provincial character of the materials that I have to compile and the great lack of uniformity of opinions among eminent geologists who have written upon the subject have been most forcibly impressed upon me. Again, when comparing the earlier and the later authors, there is a lack of uniformity in nomenclature that renders the task of one seeking information extremely difficult. Deposits of bitumen in different parts of the world have been described by persons whose knowledge of geology is often of an extremely elementary character, yet almost every author who has mentioned a tar or petroleum spring endeavors to inform his readers respecting the age of the rocks from which it issues and discusses the origin of bitumens.

A clearer comprehension of the geological occurrence of petroleum can be had without particular reference to the political divisions of the earth's surface, and I shall therefore consider the subject only with reference to geological sequence. It has been frequently remarked that petroleum occurs in all geological formations from the Silurian up to the Tertiary, and while this is true as a general statement, it is misleading, for bitumen is not uniformly distributed through all formations, but occurs principally in two epochs of geological history, the Silurian and the lower half of the Tertiary. The vast accumulations along the principal axis of occurrence in the western hemisphere are found in Silurian and Devonian rocks; but the most productive axis in the eastern hemisphere lies in the Eocene of the Carpathians and the Caucasus. An examination of the geographical occurrence of bitumen east of the Mississippi river shows that it has been reported from localities which describe an ellipse upon the border of the Cincinnati anticlinal, which is really an elevation of Silurian rocks extending from central Kentucky to lake Erie, with Cincinnati nearly in its center, and sloping beneath the newer formations in all directions. Starting with Great Manitoulin island on the north, petroleum is reported at Port Huron, Michigan; Chicago, Illinois; Terre Haute, and in Crawford county, Indiana; Henderson, Cloverport, Bowling Green, and Glasgow, Kentucky; and in the region around Nashville, Tennessee, extending southeast to Chattanooga, where the Silurian rocks again reach the surface. Turning northward, the line extends almost unbroken from Burksville through the eastern counties of Kentucky into Ohio and West Virginia, and into Pennsylvania and New York, but how far has not yet been determined. The ellipse is completed by the petroleum fields of Canada. A portion of this territory is covered with the carboniferous formation, beneath and within which petroleum has often been found.

At Great Manitoulin island petroleum was obtained in the Trenton limestone. At Chicago and at Terre Haute the drill penetrated the Niagara limestone before reaching oil. The failure of the wells to reach oil in southern Indiana is attributed by Professor E. T. Cox to the fact that they were abandoned before they reached the corniferous and the Niagara limestones. (*a*) Professor Shaler appears to regard the great Devonian black shale as the source of the oil of Kentucky. (*b*) The oil in that state is found saturating sandstone at Glasgow, and in crevices at Burksville and other points on the Cumberland, in many instances, as I am informed by those who reside in that vicinity and are familiar with the subject, beneath the black shale. In the neighborhood of Nashville, where the Lower Silurian rocks reach the surface, petroleum occurs within geodes that are inclosed within the solid mass of the blue limestone under such circumstances as to admit of no question as to whether the oil originated in the rock where found. As the occurrence of petroleum is studied in localities lying northeast of Nashville, the present location of the oil is found to be in rocks that lie in a continually ascending series. Around Burksville it is found in crevices, in a so-called marble in the Upper Silurian, immediately beneath the Devonian black slates. Further north it lies in the Devonian and subcarboniferous sandstones, and is held in the region in Johnson county partly in rocks that are now above the drainage level of the country. (*c*) In Professor J. P. Lesley's elaborate report upon this region he says: "A conglomerate age or horizon of petroleum exists; this is the main point to be stated." (*d*)

Leaving Kentucky and entering Ohio, we find the so-called oil break of West Virginia and Ohio furnishing petroleum in sandstones that lie within the coal measures. Still further to the northeast, in Pennsylvania and New York, the oil sands are all found beneath the coal measures in the Upper Devonian, and in Canada they again descend to the Lower Devonian.

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a Geological Survey of Indiana, 1872, p. 139. *b Geological Survey of Kentucky*, N. S., iii, 107. *c* Lesley, P. A. P. S., x, 33. *d Ibid.*

At Belden, Ohio, the oil is found in crevices in the Berea grit which covers a wide expanse of country in Lorain and Medina counties.

At Mecca, in the neighborhood of Power's Corners, the oil saturates the Berea grit, which lies within 80 to 100 feet from the surface. Water is pumped from the wells, bringing the oil with it. These wells are often used for water at the same time that they yield petroleum.

The geology of the trans-Mississippi localities producing petroleum has never been studied in any comprehensive or satisfactory manner. Professor G. C. Swallow says the petroleum of western Missouri and eastern Kansas comes from the coal measures, the well in La Fayette county, Missouri, passing through "sandstone, shale, coal, and limestone", and Professor Aughey reports the oil in the well at Ponca, Dixon county, Nebraska, as coming at a depth of 570 feet from the Lower Carboniferous. "The boring passed through the Cretaceous (Dakota) group, then through the Upper Carboniferous into the Lower Carboniferous, and obtained only a very small quantity of oil." Mr. S. F. Emmons says: "It (petroleum) exists in the Cretaceous rocks which extend along the eastern slope of the Rocky mountains from British Columbia to Mexico, and in many of the interior valleys." The outcrops mentioned in the last chapter as occurring in Wyoming and Colorado arise probably from the Cretaceous. I have no information respecting the geology of the outcrops in Texas.

The bitumen of the Pacific slope of Mexico, the West Indies, and South America is doubtless Tertiary Miocene in California and Eocene in Trinidad. In England the small quantity of petroleum that has been observed has sprung from the coal measures. In the valley of the Rhone and Savoy the bitumen is in Jurassic limestones. The bitumen of the Apennines, of Dalmatia and Albania, issues from rocks that are Eocene; also that of Roumania, Galicia, and the Caucasus. But little is known respecting the geology of the bitumen of Syria, Judea, and Persia. The Punjab is Eocene, and the little that is known of the deposits yielding petroleum in Burmah and the East India islands indicates that they are of the same age.

From these statements it will be seen that there is a vast area in the valley of the Mississippi, estimated at 200,000 square miles, over which petroleum has been obtained, the formations of which are nowhere newer than the coal measures. Another vast area, extending from California through Mexico to Peru, and including the West India islands, yields petroleum from Tertiary rocks, while on the eastern continent a belt of country extends from the North sea to Java, the bitumen-bearing rocks of which, so far as is known, are Tertiary. I shall have occasion to refer to many of the details of these localities in the fifth chapter. At present the bulk of the petroleum produced issues from rocks older than the Carboniferous, while the formations in by far the greater number of localities yielding bitumen are of Eocene age.

Section 2.—THE GEOLOGICAL OCCURRENCE OF PETROLEUM IN EASTERN NORTH AMERICA.

The geological occurrence of petroleum in the United States has been discussed with reference to whether it has all primarily issued from the Silurian limestones and has accumulated in the crowns of anticlinals. This view has been forcibly argued by Professor T. Sterry Hunt, of Montreal. The question has also been discussed with reference to whether petroleum, having originated in deep-seated strata, has not collected in crevices which have resulted from faulting and movement of the overlying strata. The late Professor E. B. Andrews was perhaps the leading exponent of this view. Again, it has been urged that the oil, having originated in the lower rocks of deeply-seated strata, is held neither in crevices nor beneath the crowns of anticlinals but by capillary attraction in the interstices and cracks of porous sandstone. This view has been advocated by Professor J. P. Lesley. Dr. Hunt observed in Canada, Professor Andrews in West Virginia, and Professor Lesley in Pennsylvania and Kentucky, and from a careful examination of the facts to be observed in a summer's trip through the oil region from Olean, New York, to Nashville, Tennessee, and also from a careful collation of statements made by many oil producers and others, I conclude that each of these gentlemen is correct as regards his own locality. There is no question but that petroleum has originated in the Silurian rocks, and that the finding of oil in the Niagara limestone at Chicago and at Terre Haute was a strong confirmation of the opinions expressed by Dr. Hunt in his famous essay on the history of rock-oil, when he says, referring to a previous paper reported in the *Montreal Gazette:*

> I asserted that the source of the petroleum was to be sought in the bituminous Devonian and Silurian limestones. Beside the corniferous limestones (Devonian), we have shown that both the Niagara and Trenton (of Upper and Lower Silurian age) contain petroleum. (a)

There is no question that petroleum occurs in West Virginia along an anticlinal, as has been advocated by Professor Andrews. The hypothesis that petroleum occurs in huge fissures or cavities which have been represented by sections, in which water, oil, and gas are arranged according to their specific gravities, has not been sustained by later and more careful study of the subject. It is beyond question that the oil of Pennsylvania does not occur beneath anticlinals, nor in crevices, nor is it anywhere near the Silurian limestones; yet there is no doubt that at Gaspé and in Ontario the springs of petroleum occur along the crests of gentle anticlinals, as so carefully described by Dr. Hunt.

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a C. N., vi, 5, 16, 35; C. Nat. (1), vi, 245; A. J. Ph. (3), x, 527.

In 1867 Professor C. H. Hitchcock contributed an article to *The Geological Magazine*, which has been very widely quoted, particularly as to the conclusions therein reached. These conclusions appear to have been obtained from a collation of the writings of Professors Hunt, Andrews, and Lesley; (*a*) and an address given by Dr. Hunt at a meeting of the Société Geologique de France, in which he made a general application of his views, based on his Canadian experience, to the occurrence of petroleum in the United States, appears to have been very widely quoted in Europe. (*b*)

In the article above mentioned Professor Hitchcock enumerates fourteen different formations from which petroleum has been obtained in North America (exclusive of the West Indies), and generally in commercial quantities. These are:

a. Pliocene (*c*) Tertiary of California. This has been known for a century.
b. Cretaceous in Colorado and Utah, near lignite beds. Not yet explored.
c. Trias of North Carolina and Connecticut, in small amounts. (*d*)
d. Near the top of the Carboniferous rocks in West Virginia. Most of the producing wells of this state are from this horizon.
e. Shallow wells near Wheeling, West Virginia, and Athens, Ohio, not far from the Pittsburgh coal.
f. Four hundred and twenty-five feet lower, near the Pomeroy coal-beds.
g. At the base of the coal measures, in conglomerates or millstone grit.
h. Small wells in the Archimedes limestone (Lower Carboniferous) of Kentucky.
i. Chemung and Portage groups—certainly three different levels—in western Pennsylvania and northern Ohio.
j. Black slate of Ohio, Kentucky, and Tennessee, or the representatives of the New York formation from the Genesee to the Marcellus slates. This is near the middle of the Devonian.
k. Corniferous limestone and the overlying Hamilton group in Canada West, extending to Michigan. This is largely productive.
l. Lower Helderberg limestone at Gaspé, Canada East. This is Upper Silurian.
m. Niagara limestone near Chicago, and awaits development. (*e*)
n. In the equivalents of the Lorraine and Utica slate and Trenton limestone of the Lower Silurian in Kentucky and Tennessee. One well in Kentucky in these rocks was estimated to have yielded 50,000 barrels. (*f*)

Developments since 1867 have added little, if anything, to the above as a general statement. With particular reference to the three localities in Canada, Pennsylvania, and West Virginia, which practically yield the petroleum product of North America, I shall endeavor to show the manner in which nature has stored and yields such vast accumulations of material, and to present the ascertained facts without bias for any theory. Dr. Hunt has been a frequent contributor to the literature of this subject during the last twenty years, and from his articles in the *American Journal of Science* for March, 1863, (*g*) and November, 1868, (*h*) I make the following extracts, which embody his views upon the geological occurrence of petroleum in Canada:

The natural oil-springs which occur in various parts of western Canada are upon the outcrop of the corniferous limestone or of the overlying Hamilton shales, and are along the line of a broad and low anticlinal, which runs nearly east and west through the district. In the township of Dercham, where small quantities of oil rise to the surface in several places, the corniferous formation is overlaid by about 40 feet of clay and sand, after sinking through which the limestone was bored to the depth of 36 feet. From this opening a few barrels of petroleum were obtained. Oil-springs abound for several miles along the Thames about 60 miles to the westward of Dercham, and borings into the limestone beneath have furnished considerable quantities of oil, although not sufficient, perhaps, to be of great economic importance. The principal oil-wells of Canada occur in Enniskillen, about 20 miles to the northward of the last. Here numerous oil-springs are found, and the thickened petroleum, mixed with earthy and vegetable matters, forms layers of considerable extent at the surface of the ground and around the roots of growing forest trees. Two of these layers have together an area of more than two acres, and a thickness which varies from a few inches to 2 feet. They are locally known as gum beds. In sinking a well in the vicinity of an oil-spring in this region there was found beneath a depth of 10 feet of clay and reposing upon 4 feet of gravel a layer of bituminous matter like that just described from 2 to 4 inches in thickness. It is easily separable into thin laminæ, which are so soft as to be flexible, and show upon their surfaces the remains of leaves and of insects which have become imbedded during the slow accumulation and solidification of the bitumen. This little deposit, which is mingled with a considerable proportion of earthy matter, is instructive as showing the manner in which beds of bituminous rock may sometimes be produced from previously-formed sources of petroleum.

The corniferous limestone in Enniskillen is overlaid by about 200 feet of marls and soft shales, abounding in the characteristic fossils of the Hamilton formation. To this succeed from 40 to 60 feet of Quaternary clays and sands of fresh-water origin, through which the scanty natural oil-springs rise. On sinking wells there is generally found reposing immediately upon the shales a layer of coarse gravel holding large quantities of petroleum, which is the oil of the so-called surface wells, and has accumulated beneath the clays. It is darker and thicker than that obtained directly from the rock below, on boring which fissures or seams are met with, from which petroleum issues in abundance, and often with great force, sometimes attaining the surface and often rising above it, constituting the flowing wells. These oil-bearing veins are met with at depths varying from 40 to 100 and 200 feet in the rock, and in borings near together the oil is often met with at very unequal depths. Adjacent borings sometimes appear to be connected with the same vein and to affect each other's supply. The deepest well in this region was estimated to yield, when first opened, 2,000 gallons in twenty-four hours, and, at present, where it is allowed to flow for some time, the supply in many of the neighboring shallower wells is found to fail. The facts observed in this region seem to show that these veins are fissures running obliquely downward to the great reservoir of petroleum, which is probably in the underlying corniferous limestone. The oil-wells in this township are confined to two districts, the more abundant one being about 6 miles south of the other. From the results of an unsuccessful boring made on an intermediate point, it appears that these two districts are on two slight anticlinals subordinate to the great axis already mentioned. This anticlinal structure appears to be a necessary condition of the occurrence of abundant oil-wells; the petroleum, being lighter than water, accumulates in porous strata, or in fissures in the higher part of the anticlinal, and, in obedience to a hydrostratic law, rises through openings to heights considerably above

a C. N., 6, 5, 16, 35; C. Nat. (1), 6, 245; A. J. Ph. (3), 10, 527.
b B. S. G. F., xxiv, 570.
c Since determined to be Miocene.
d Professor Kerr, state geologist of North Carolina, reported that no petroleum was known in that state.
e Since shown in Niagara limestone at Terre Haute, Indiana.
f *The Geol. Mag.*, iv, 34.
g A. J. S. (2), xxxv, 169.
h *Ibid* (2), xlvi, 356.

the water level of the region. Large quantities of light carburetted hydrogen gas are found in the palæozoic rocks of the vicinity, and seem to be in many cases accumulated in the subterranean anticlinal reservoirs, since borings sometimes yield both gas and oil, or gas alone. Water sometimes, but not always, more or less saline often accompanies the petroleum, and frequently replaces the latter in wells that have been for some time wrought. I do not conceive that the gas has any necessary connection with the oil, since large quantities of it are found in rocks which underlie the corniferous limestone. If, however, as is not improbable, portions of it were generated and now exist in a condensed state in the oil-bearing strata, its elasticity would help to raise the petroleum to the surface.

The accumulation of the petroleum along lines of uplift, and its escape through the fissures accompanying this disturbance, must evidently date from a remote geological epoch. Porous beds, like the Devonian sandstones or the Quaternary gravels, have, however, served as reservoirs in which the oil has accumulated, while argillaceous and nearly impervious strata, like the marls of the Hamilton group and the fresh-water clays which overlie the gravels in western Canada, have in a great measure prevented its escape.

Hence it would appear that the Devonian sandstones of Pennsylvania and northeastern Ohio are filled with oil which has risen from the limestone beneath, while over a great portion of western Canada this limestone was ages ago denuded, and has lost the greater part of its petroleum. (*a*)

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There exists in southwestern Ontario, along the river Saint Clair, an area of several hundred square miles underlaid by black shales in the counties of Lambton and Kent, of which only the lower part belongs to the Hamilton group. These strata are exposed in very few localities, but the lower beds are seen in Warwick, where they were many years since examined by Mr. Hall, in company with Mr. Alexander Murray, of the geological survey of Canada, and were by the former identified with the Genesee slate forming the summit of the Hamilton group. They are in this place, however, overlaid by more arenaceous beds, in which Professor Hall at the same time detected the fish remains of the Portage formation. The thickness of these black strata, as appears from a boring in the immediate vicinity, is 50 feet, beneath which are met the gray Hamilton shales. * * * * The Hamilton shale, which in some parts of New York attains a thickness of 1,000 feet, but is reduced to 200 feet in the western part of the state, consists in Ontario chiefly of soft, gray marls, called soapstone by the well-borers, but includes at its base a few feet of black beds, probably representing the Marcellus shale. It contains, moreover, in some parts beds of from 2 to 5 feet of solid gray limestone holding silicified fossils, and in one instance impregnated with petroleum, characters which, but for the nature of the organic remains and the underlying marls, would lead to the conclusion that the Lower Devonian had been reached. The thickness of the Hamilton shale varies in different parts of the region under consideration.

From the record of numerous wells in the southeastern portion it appears that the entire thickness of soft strata between the corniferous limestone below and the black shale above varies from 275 to 230 feet, while along the shore of lake Erie it is not more than 200 feet. Further north, in Bosanquet, beneath the black shale, 350 feet of soft gray shale were traversed in boring without reaching the hard rock beneath, while in the adjacent township of Warwick, in a similar boring, the underlying limestone was attained at 396 feet from the base of the black shales. It thus appears that the Hamilton shale (including the insignificant representative of the Marcellus shale at its base) augments in volume from 200 feet on lake Erie to about 400 feet near to lake Huron. Such a change in an essentially calcareous formation is in accordance with the thickening of the corniferous limestone in the same direction.

The Lower Devonian in Ontario is represented by the corniferous limestone, for the so-called Onondaga limestone has not been recognized, and the Oriskany sandstone, always thin, is in some places entirely wanting. The thickness of the corniferous in western New York is about 90 feet, and in southeastern Michigan it is said to be not more than 60 feet, although it increases in going northward, and attains 275 feet at Mackinac. In the townships of Woodhouse and Townsend, about 70 miles west from Buffalo, its thickness has been found to be 160 feet; but for a great portion of the region in Ontario underlaid by this formation it is so much concealed that it is not easy to determine its thickness. In the numerous borings which have been sunk through this limestone there is met with nothing distinctive to mark the separation between it and the limestone beds which form the upper part of the Onondaga salt group or Salina formation of Dana, which consists of dolomites, alternating with beds of a pure limestone, like that of the corniferous formation. The saliferous and gypsiferous magnesian marls, which form the lower part of the Salina formation, are, however, at once recognized by the borers, and lead to important conclusions regarding this formation in Ontario. In Wayne county, New York, the Salina formation has a thickness of from 700 to 1,000 feet, which, to the westward, is believed to be reduced to less than 300 feet, where the outcrop of this formation, crossing the Niagara river, enters Ontario. * * * *

Apart from the chemical objections to the view which supposes the oil to be derived from the pyroschists above the corniferous limestone, it is to be remarked that all the oil-wells of Ontario have been sunk along denuded anticlinals, where, with the exception of the thin black band sometimes met with at the base of the Hamilton formation, these so-called bituminous shales are entirely wanting. The Hamilton formation, moreover, is never oleiferous, except in the case of the rare limestone beds already referred to, which are occasionally interstratified. Reservoirs of petroleum are met with both in the overlying Quaternary gravels and in the fissures and cavities of the Hamilton shales, but in some cases the borings are carried entirely through these strata into the corniferous limestone before getting oil. Among other instances cited in my geological report for 1866 may be mentioned a well at Oil Springs, in Enniskillen, which was sunk to a depth of 456 feet from the surface, and 70 feet in the solid limestone beneath the Hamilton shales, before meeting oil, while in adjacent wells supplies of petroleum are generally met with at varying depths in the shales.

In a well at Bothwell oil was first met with at 420 feet from the surface and 120 feet in the corniferous limestone, while a boring at Thamesville was carried 332 feet, of which the last 32 feet were in the corniferous limestone. This well yielded no oil until, at a depth of 16 feet in this rock, a fissure was encountered, from which at the time of my visit 30 barrels of petroleum had been extracted. At Chatham, in like manner, after sinking through 294 feet of shales, oil was met with at a depth of 58 feet in the underlying corniferous limestone.

We also find oil-producing wells sunk in districts where the Hamilton shale is entirely wanting, as in Maidstone, on the shore of lake Saint Clair, where, beneath 109 feet of clay, a boring was carried through 209 feet of limestone, of which the greater part consisted of the water-lime beds of the Salina formation, overlaid by a portion of the corniferous. At a distance of 6 feet in the rock a fissure was struck, yielding several barrels of petroleum. Again, at Tilsonburg, where the corniferous limestone is covered only by Quaternary clays, natural oil-springs are frequent, and by boring fissures yielding petroleum were found at various depths in the limestone down to 100 feet, at which point a flowing well was obtained, yielding an abundance of water, with some 40 gallons of oil daily.

The supplies of oil from wells in the corniferous limestone are less abundant than those in the overlying shales and even in the Quaternary gravels, for the obvious reason that both of these offer conditions favorable to the retention and accumulation of the petroleum escaping from the limestones beneath.

* * * * The conditions under which oil occurs in these limestones in Ontario are worthy of notice, inasmuch as they present grave difficulties to those who maintain that petroleum has been generated by an unexplained process of distillation going on in some

a A. J. S. (2), xxxv, 169.

underlying hydrocarbonaceous rock. Numerous borings in search of oil on Manitoulin island have been carried down through the Utica and Lorraine shales, but petroleum has been found only in fissures at considerable depths in the underlying limestones of the Trenton group. The supplies from this region have not hitherto been abundant, yet from one of the wells just mentioned 120 barrels of petroleum were obtained. The limestone here rests on the white, unfossiliferous, chazy sandstone, beneath which are found only ancient crystalline rocks, so that it is difficult to avoid the conclusion that this limestone of the Trenton group is, like those of the Upper Silurian and Devonian age already noticed, a true oil-bearing rock. (*a*)

Although the discussion of the subject as presented in these two extracts proceeds in a somewhat disconnected manner, the opinions held by Dr. Hunt are plain, viz: that the oil comes from the limestones at the base of the Devonian formation, that it is indigenous in those rocks, and has accumulated under the crowns of anticlinals.

According to the latest published researches, I conclude that the geological formations in western Pennsylvania from which petroleum has been obtained belong to the Chemung and perhaps later groups of the Upper Devonian, and consist of shales and marls, interstratified with sandstones. The sandstone varies in character from a coarse-grained, uncemented sandstone to a pebble conglomerate, composed of worn pebbles of white or slightly-colored opaque quartz overlaid by marls and slates, often highly silicated, forming very hard and impervious crusts. This pebble conglomerate consists of two varieties, occupying separate horizons, in one of which the pebbles are nearly spherical, and in the other flattened. Between these beds of sandstone or conglomerate that contain the oil are beds of shale, often of great thickness, with which are thin beds of sand and "shells". The latter are thus described by Professor J. P. Lesley:

The hard "shells" or crusts of white flint found at different depths in this and many other wells, and broken with the auger-bits only with extreme difficulty, are deserving of particular investigation. They seem to form impervious sheets of precipitated silica effectual barriers against any general movement, upward or downward, of the underground drainage. (*b*)

The sandstones and conglomerates are of quite uniform structure over wide areas; for instance, the Venango third sand consists of smooth, rounded pebbles, while the Bradford third sand is a porous sandstone. The latter has been examined microscopically by Professor C. W. Hall, of the University of Minnesota, who, in a private communication, says:

The sandstone in the flame turned to a light gray, almost white, color through the burning out of the bituminous matter. Thin sections disclose the presence of numerous fluid cavities in some of the grains. Small as these grains are, they protected intact the fluid contents of the cavities from the penetrating effects of the petroleum which had percolated through the mass of the sandstone.

A bed of shale several hundred feet in thickness and very rich in remains of fucoids outcrops along the shores of lake Erie through Erie county, Pennsylvania, and Chautauqua county, New York, and wells drilled at Erie, Pennsylvania, to a depth of over 600 feet in this shale have yielded petroleum, but have failed to reach the underlying formation. These shales dip toward the southwest.

At Union City, in the southern part of Erie county, sandstone overlies the shale in the summits of the hills and furnishes the quarry rock for the valley of French creek. This sandstone often exhibits traces of bitumen, and when freshly quarried and exposed to the sun becomes covered with an exudation of thick oil. Farther south and east the rocks alternate between shales, sandstones, and pebble conglomerate, each of which dips south and west, and disappears under newer and higher members that succeed them on the surface. In the neighborhood of Titusville, Crawford county, the shales of Erie county have passed far below the surface, and new sandstones have appeared on the hills which border the deep and narrow valleys through which the Allegheny and its tributaries flow.

No clearer statement has been made of the relations of these rocks than that given by Mr. J. F. Carll in his reports to the geologist in charge of the second geological survey of Pennsylvania. He says:

In the first oil development by artesian wells nothing was known about the sands. Wells were drilled until indications of oil appeared, without regard to the character of the strata pierced. But experience soon proved the sand rocks to be its source, and then commenced deeper drilling for other sands, which, in the valley of Oil creek, resulted in the discovery and classification of "three sands"—these being all the oil-bearing sands found in that locality, even after several wells had been sunk much deeper in quest of others.

In the progress of development locations for wells were selected on higher ground. The drill passed now through four or five other and higher definite sand rocks before reaching the geological horizon of the *first sand* of Oil creek, and when this fact was made clear it became customary among drillers to throw out these *upper* sands from their well records. They were called the "mountain sands", and were also numbered 1, 2, 3, etc. The drillers commenced their count of the oil-rocks with that one which they found at the depth at which they supposed the first sand of Oil creek to lie; but in so doing many errors occurred, resulting from a want of accurate observation, first, as to the surface elevation of the wells drilled on high ground, and, second, as to the dip of the oil-bearing strata, which materially affected the comparison of elevations, even when these were accurately known. A third source of error may be found in the fact that a thick stratum of sand lying single and solid in one place is often split into two, or, in other words, is represented by an equivalent of two sands with shales intervening in another place, perhaps only a short distance from the first.

For several years after the discovery of oil the drilling of wells was almost exclusively confined to the "flats" bordering the principal streams. The impression prevailed that there was some connection, some parallelism, between the streams on the surface and the "oil veins" beneath; but many failures to strike oil along the streams gradually led to locations on higher ground and upon lines between good wells. This method has been pursued so long and so thoroughly that we can now affirm that the drill has traced the great oil leads of the country from point to point *regardless of any and all topographical features of the surface.* (*c*) * * *

We use the word "belt", not as employed by some to designate a narrow, continuous line of sand rock, which may be unerringly traced for miles with an instrument on a certain degree of the compass circle, but only as a convenient term for expressing the general trend of the oil-bearing rocks from point to point, even although interrupted by "dry" and unproductive intervals.

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a A. J. S. (2), xlvi, 356, *et seq.* *b* P. A. P. S., x, 68. *c* Report I, p. 10.

The base-line run from Pleasantville to Tidioute—from the commencement of the Colorado district to the Allegheny river—passes through what has been one of the best and most continuous oil-producing belts of the region. Along and contiguous to this line, and to the north of it, the deeply-eroded valleys of Pine creek and Dennis run expose the basset edges of the whole series of slightly-inclined rocks (uplifted toward the north) underlying the Great Conglomerate (No. XII, the base of the productive coal measures) to a (geological) depth of 850 feet, bringing us down to within about 100 feet of the third or lowest oil-bearing sands. (*a*)

This exposure (along Pine creek and Dennis run), taken in connection with the well records along the route, enables us to form a tolerably correct idea of the stratification of the rocks to that depth. The whole series is found to consist of bands of sandstones and conglomerates and sandy and muddy shales and slates, varying locally in character, composition, and relative order, when studied in detail, but, as a whole, lying one above another in nearly horizontal parallel planes. The local variability of stratification is particularly noticeable (at least in the southeastern part of the district) in the strata next beneath the Conglomerate No. XII, and to a relative depth of from 600 to 650 feet. These strata have never produced oil in Venango county. We may therefore call them the "barren oil measures" of Venango, or the "mountain-sand group".

Beneath the division of mountain sands another series, with a thickness of from 350 to 400 feet, and similar to the above in structure, but rather more regular in stratification, will include the three sands of Oil creek; and, as we believe it can be shown that no oil has ever been obtained in the district except from rocks of this series, it may properly be called the "petroleum measures" of Venango, or "division of the three sands".

Some of the first wells drilled evidently obtained their oil above the first sand, and the old oil-pits of French and Oil creeks and Hosmer run were above it also. But the oil, without doubt, came really from the first sand, its close proximity to the surface in these places having admitted of the percolation of surface water into its crevices, which, by hydraulic pressure, forced the oil upward.

It is a noticeable fact that any first sand below the surface is generally full of water veins, whether it be an oil-bearing or a mountain sand. If the oil sands lie deep, they seldom (especially in new territory, before the water is let down by the drill) contain much water.

In the shallow wells at Tidioute, along the Allegheny river, and on French and some parts of Oil creek, considerable water was always pumped with the oil; but in the deep wells at Pleasantville there was not found at first one per cent. of water, and that, being salt, must have come commonly from the second sand. As the oil was exhausted the water increased. (*b*)

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A comparison of records of wells on Oil creek, where the three leading sands of the petroleum measures lie with considerable regularity, both as to their thickness and the intervening distances between them, results in an average record about as follows:

First sand, 40 feet thick; interval, 105 feet. Second sand, 25 feet thick; interval, 110 feet. Third sand, 35 feet thick. Total, 315 feet.

In addition to these three regular sands, there is found in many of the wells a fine-grained, muddy, gray sand, known among drillers as the "stray third". This lies from 15 to 20 feet above the regular third, and is from 12 to 25 feet thick. In some localities this rock assumes a pebbly character, and produces oil which is always darker than the third-sand oil, sometimes being nearly black.

At different points on Oil creek—at East Shamburg and other places—wells in close proximity to each other have produced, some of them black oil, some green, and some a mixture of both.

The "black oil" of the Pleasantville district has all been derived from the "stray third", which, in this district, is universally called the fourth, or "black-oil sand". But here the character and composition of the two sands (third and stray) are reversed. The stray is a coarse pebble or conglomerate; the third, a fine, micaceous, muddy, gray sand, only 15 to 20 feet in thickness, but always showing traces of green oil, and sometimes furnishing an abundance of gas.

We believe it can be shown also that Pithole, Cashup, and Fagundus, although producing an oil of a lighter color than Pleasantville, drew their supply from the same stray sand, and the proof will be offered farther on.

A noticeable peculiarity of these two sands (stray and third) is that on the northwestern outline of the oil-field, where the third shows itself in greatest force, the stray is seldom an oil-producing rock. As we proceed southeastward the stray begins to get its pebbly constitution and to yield oil over broader areas than the third, the latter becoming more fine and compact and gradually thinning away.

A marked difference will be noted also on comparison of specimens of the two sands. In the oil-producing stray the pebbles are of a yellowish-brown color, and in shape generally spheroidal. In the third the pebbles are white, often brilliant, and in shape lenticular. These distinguishing characteristics, we believe, hold good universally.

On the northwesterly line above mentioned the second sand lies in a massive stratum, 30 feet or more in thickness. Toward the southeast, as in a part of the Pleasantville district, at Bean farm, Pithole, Cashup, and Fagundus, it is split into two well-defined sands, with from 15 to 30 feet of slates or shales intervening. It is this that has given rise to the erroneous appellation of fourth-sand oil at Pleasantville. The drillers began to number rightly on the first; and called the split (second) sand next below it second and third, and then called the stray the fourth. This, of course, made the third sand of the Oil creek wells, which was still lower, fifth in the series.

In some localities they went still farther in their zeal to prove their territory better than Oil creek, by showing a greater number of sands. Finding the stray and third in three divisions, instead of two, they announced at once the discovery of a sixth sand.

The first sand, as far as we have examined it, appears to lie with more uniformity than the second, but further investigation may show changes of character and of level similar to the others.

Little oil has been produced from the first and second sands in the particular field under review. Their best development as oil-bearing rocks is along the Allegheny river from West Hickory to the Cochran farm, and on French creek and Two-mile run, near Franklin, to which our detailed survey of 1874 did not reach. We speak of them above as they are found on the green-oil range, and without a closer knowledge of the peculiar structural differences which they may be found to exhibit in the places above named on the Allegheny river and French creek.

Assuming, then, that all the oil from this country has been deduced from the "group of the three oil sands", consisting of the first, second, stray, and third, with their intervening slates, shales, and mud rocks, and that the trend of the oil-producing belt is marked by no surface indications to point out its direction or drift, we will proceed, on the principle of a general parallelism of strata, to trace the sands by means of the levels run, combined with the records of wells, through some of the main oil centers of the district, with a view of ascertaining the direction of the dip of the series and the fall, in feet, per mile.

The Venango petroleum district, or "upper oil belt", as it is now generally called, in contradistinction to the Butler county district, may be said to commence a short distance east of Tidioute. From thence southwestward it is marked by an almost unbroken band of wells through Dennis run, Triumph, the Clapp farms, New London, the Ware farm, and Colorado, a distance of about 9 miles.

Between this, its southwest end, and the commencement of the Shamburg district, near the National wells, no paying third-sand wells are found, except, perhaps, within a limited area on the Benedict farm, west of Enterprise, the exact geological relations of which to the Colorado "lead" has not been fully determined.

a Report I, p. 11. *b* *Ibid.*, p. 13.

Beneath this unproductive district the third sand is found in all the wells drilled, having a thickness of from 30 to 45 feet, but apparently too fine-grained and closely compacted with mud to produce oil.

Between Shamburg and Petroleum Centre, on Oil creek, occurs another unproductive interval; but from Petroleum Centre the oil-belt has been traced with considerable continuity, crossing the Allegheny river at Reno, again at Foster's, and terminating at Scrubgrass.

This line of development, it will be noted, leaves Tidioute in a direction of about south 80° west, gradually sweeping around toward the south, and ending with a bearing of only about south 20° west.

The belt above described, it should be understood, is the green-oil or third-sand belt. It appears to be much narrower and more sharply defined than others. At many places a distance from the center line toward the north or toward the south of merely a few rods suffices to guarantee a "dry hole".

From levels taken along the surface line above described, combined with such records of wells as were obtained, the elevation of the top of the third sand in the several localities named is ascertained to be as follows:

	Feet above tide.
At Tidioute	995
At Colorado	840
At Pleasantville	755
At Shamburg	710
At Petroleum Centre	640
At Rouseville	545

Distance from Rouseville to Tidioute, 20.7 miles; difference in elevations, 450 feet; dip per mile, 21.7 feet. (*a*)

In the report made subsequently, and published in 1880, Mr. Carll continues the discussion of this subject. Want of space forbids my quoting more liberally from this report, but the following extracts present the relation and stratigraphy of these formations:

The designations first, second, and third mountain sands, used provisionally in 1874, answered very well for the purposes of that local report; but to adhere to the use of these ordinal numbers still, after the comparison of oil-well and surface sections has been extended southwestward to the very borders of the state of Ohio and northeastward into the southern counties of the state of New York, would only perpetuate confusion in our geological nomenclature.

The first mountain sand appears to occupy the horizon of the Connoquenessing sandstone of Butler county and the Kenzua creek sandstone of McKean county, and may as well be spoken of when occasion requires under one of those two names.

In the *Reports of the Pennsylvania Survey*, vol. III, page 83, appears the following in relation to this subject:

The second mountain sand cannot, indeed, be robbed entirely of its name; but whenever it is thus spoken of the name must be accounted as a mere synonym for the Garland conglomerate, and not at all as an index to the numerical position of the rock in relation to other sands in the series. But it will always be the Garland-Olean-Sharon-Ohio conglomerate.

The third mountain sand will receive in this report a new name, the Pithole grit. This rock was first recognized as a persistent sandstone in the Pithole oil-wells, being well developed in all that country, and making conspicuous outcrops along the Allegheny river on the south, and along Oil creek on the west. The term *grit* sufficiently designates it as a sandstone; but, what is more important, will serve to associate it in the reader's mind with the Berea grit of Ohio, which seems to have been a contemporaneous formation, although the two rocks have not been traced across the country toward each other to a common place of actual meeting.

Neglecting for the present the mountain sands as separate numbers of a small series, and grouping them and their intervals together as a whole, I must now show that they constitute one (and the upper) member of a larger series. The vertical section of rocks in the oil belt, as exhibited by the well records, show these characteristic subdivisions:

1. Mountain sands, so called by the oil-well drillers.
2. Crawford shales, a group of shales and mud rocks, in the midst of which is the Pithole grit.
3. Venango oil-sands, a group of sandstones and shales interleaved.

These names will be useful in defining those features of hardness and softness by which the driller classifies the rocks through which his well passes downward; but they must not be taken by the geologist to signify formations of these successive and distinct ages, plainly and absolutely separated from each other; for such dividing planes cannot be satisfactorily established from the imperfect records of oil-wells alone.

It is important to state the fact clearly at the outset that throughout the whole area which has afforded the Venango oil—that is, along the entire length of the oil-producing belt (or belts) of country—the structure of the oil-sand group is virtually the same. On the other hand, the moment we leave the oil-producing area to the right or to the left the internal constitution of the oil-sand group becomes quite different. All the wells that pierce the oil-producing belts exhibit remarkably the same group of oil sands. All wells put down outside of these belts exhibit quite a different kind of deposits when they reach the plane of the oil sands. (*b*)

From data too voluminous to quote here, Mr. Carll concludes that "the Venango oil sands as a group not only thin away, but disappear, and are wanting in the Slippery Rock country". Farther to the southwest, in Beaver county, he concludes that "not only is the oil group cut out, and also the red rock over it, but the sandstone deposit occupying the horizon of the Pithole grit is enlarged; the shaly interval above the sandstone becomes sandy; and thus the true base of the mountain-sand series becomes somewhat obscure". He further concludes:

It follows from this study of our sections that the Ohioville (Smith's ferry) amber oil must be derived from the horizon of the Pithole grit, which also furnishes *amber oil* in small quantities on Slippery Rock creek. It follows as logically, also, that the Slippery Rock heavy oil is found in one of the lower members of the mountain-sand series, an horizon which also produces heavy oil in many wells at Smith's ferry. (*c*)

Continuing the discussion, Mr. Carll states:

No direct connection has yet been discovered between the upper or Tidioute-Bullion oil belt and the lower or Clarion-Butler oil belt. The present southern termination of the line of productive wells on the upper belt is near Clintonville, in Venango county. This is about 12 miles northwest of Columbia hill, in Butler county, which is the nearest point of development in the lower belt. The lower belt

a *Report Second Geological Survey Pennsylvania*, I, 1874, p. 18. *b* *Ibid.*, III, p. 83. *c* Reports, III, p. 90.

is known to extend south-southwesterly from Columbia hill into Summit township, Butler county, some 20 miles, and northeasterly into Elk township, Clarion county, some 15 miles. The area of country between the belts has been tested in hundreds of places with results in most cases quite unsatisfactory. Nevertheless several good pools of oil have been discovered. These, however, do not establish a connection between the belts, for the stratification is somewhat irregular throughout all this district as far as is known, and the continuity of the oil-producing rocks seems to be here interrupted. We cannot, therefore, speak of the upper belt as being directly connected by a line of paying wells with the lower; yet the main structural features of the group in the upper belt are observable across the interval and the rocks themselves reappear with their characteristic aspect as soon as the lower belt is reached.

That the deposits of the lower belt have been subjected to more vicissitudes of water level than those of the upper belt, resulting in a greater number of alternating bands of sandstone and shale within the vertical limits of the group, seems evident; yet it cannot be doubted that the deposit in the two belts were being laid down at one and the same time. They occupy the same geological horizon; they are associated with similar strata; and they exhibit a like parallelism of structure. Geologically, therefore, the two belts may be viewed as one, and may be studied and described accordingly. (*a*)

Concerning the geological age of the oil-sand group, Mr. Carll remarks:

Previous to our present survey the Venango oil-sands were universally regarded as of Chemung age. In the summer of 1875 evidences began to accumulate pointing strongly toward the probability that they were of more recent date; but the idea seemed then so heterodox, and the facts to support it were at first so meager and questionable, that no definite conclusion on the subject could be immediately arrived at. Even now their relative place in the paleozoic column of eastern Pennsylvania cannot be precisely and positively indicated. We can only say there are reasonable grounds for inferring that they do not belong to the Chemung formation, as represented in New York state and eastern Pennsylvania. (*b*)

A comparison of the structure and depth of sediment belonging to the Catskill, the Pocono, and the Mauch Chunk periods in eastern Pennsylvania with those of the same ages in western Pennsylvania leaves little room to doubt that the former represent deposits in a much broader and deeper sea than the latter: a sea perhaps whose bottom was undergoing a steady depression in the east while it was alternating between depression and elevation and gradually shallowing in the west. An elevation of the ocean bottom near the close of the Chemung period seems to me to have thrown off the waters from a large portion of its former bed in the west, leaving submerged in that direction only a narrow arm of the sea, representing perhaps some old submarine valley. This comparatively contracted and shallow basin must necessarily, from the very nature of the case, have been the repository of immense deposits of reworked Chemung sediments, rapidly brought into it from the newly emerged mud-land, to be interbedded with the Catskill reds, which were intermittently swept in from the east to greater or less distances as circumstances directed. We might then expect to find in this basin precisely what the drill discloses: alternations of Catskill red and Chemung gray argillaceous shales occupying the deepest part of it, and more sandy deposits lying around its edges. (*c*)

Concerning the structure of the oil-sand group, Mr. Carll insists that the integrity of the Venango oil-sand group must be kept in clear view, as it is a group in the strictest sense of the term, and has a well-defined top and bottom. (*d*) The sandy layers at the top of the Crawford shale are of no moment in the present discussion. The sole fact here insisted on is this:

1. That over the oil-sand group lies a distinct soft formation, 300 or 400 feet thick, in all parts of the oil regions of western Pennsylvania, which, for the present, we call the Crawford shale, in the middle of which appears, in some parts of the region, a massive sand deposit, called in this report the Pithole grit.

2. That the well-sinker will find an abrupt change of character when he gets through this soft formation and strikes the top of the oil-sand group. The transition from the soft Crawford shales or slates to the first oil sand is sharply defined, and the geologist is obliged to see here the close of one period of deposits of one kind and the beginning of another period of deposits of a very different kind. (*e*)

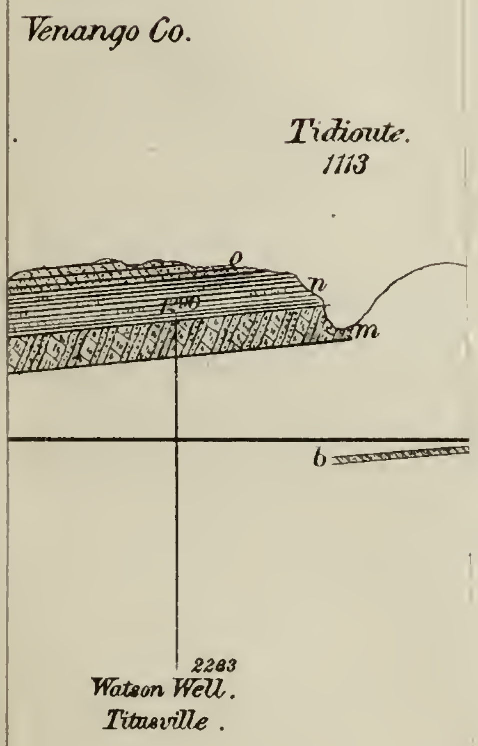
Mr. Carll continues:

Under the oil-sand group again lies a perfectly well-marked different formation. The driller having gone through the Venango oil sands and their separating shales and reached the base of the group, suddenly, by as abrupt a transition as that he encountered at its top, enters a different set of rocks. Wherever the group is normally developed the drill passes at once from sandstone into shale, and continues from that point in the well to go steadily down through shales for hundreds of feet without encountering any sandstone layers like those above.

A large majority of oil-wells were never drilled below the third sand or base of the group, for experience had convinced operators that it was useless to expect another sand layer below that horizon along the whole line of the Venango and Butler belts. Several hundred wells, however, were put down to depths of from 100 to 500 feet beneath the lowest Venango oil sand. Their numbers, and the extent of ground over which they lie scattered, afford conclusive evidence that the measures beneath the oil-sand group have everywhere the same clay characters. The universal testimony of their records is, soft drilling and no coarse, massive sand rock after leaving the productive oil measures. Occasionally, indeed, a "sand" has been reported, and some fine-grained sandstone layers were to be expected, for they are not unknown in the Chemung series; but it is now conceded that such layers do not resemble the oil sands, and that they occurred so rarely, and the reports of them are so vague and questionable, that we are warranted in treating them as mere local variations of some of the beds of the Chemung shales. (*f*)

The Venango oil-sand group itself is a mass of sandstone deposits from 300 to 380 feet thick, with layers of pebbles and many local partings of shale and slate. These figures may be varied somewhat, but it will be found as a general rule that a thickness of 350 feet will, in nearly every case, embrace all the sands belonging to the Venango group, even the fourth, fifth, and sixth sands, as the lower members of the group in some localities have been called. It is wonderful how the group maintains its total thickness with such uniformity for a distance of 62 miles in a straight line from Tidioute, in Warren county, to Herman station, in Butler county. The top sand is sometimes 10 feet thick, and sometimes 85 feet; the bottom sand may be 5 feet thick, or it may be 120 feet; and so either one of these members may individually vary in thickness about as much as the whole group is found to vary. (*g*)

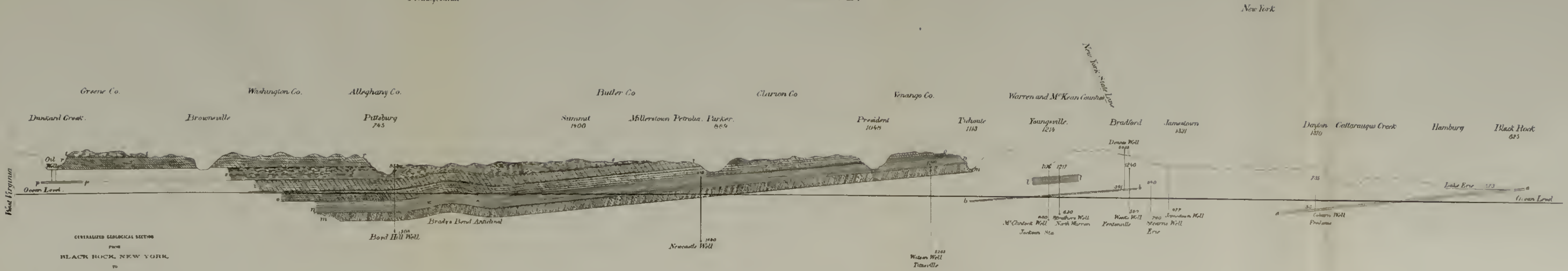
a Reports, III, p. 100.
b *Ibid.*, p. 119, § 297.
c *Ibid.* p. 122, § 302.
d *Ibid.*, p. 128, § 315.
e *Ibid.*, p. 130, § 318.
f *Ibid.*, p. 132, § 320.
g *Ibid.*, p. 136, § 323.



Formations.

Limestone.
3rd. Sand.
Group.
oup including Butler, Clarion and V
Shales.
ate Measures including Oil on Sli
oductive Coal Measures.
rren Coal Measures.
l Measures including "Pittsburg Co
ren.
Sandstone

Plate VII.



GENERALIZED GEOLOGICAL SECTION
FROM
BLACK ROCK, NEW YORK,
TO
DUNKARD CREEK, PA.,
Showing the various oil horizons of
CANADA, NEW YORK AND PENNSYLVANIA,
AND THEIR RELATIVE POSITIONS IN THE
PALÆOZOIC SYSTEM.
COMPILED BY
JOHN F. CARLL,
FOR THE
Second Geological Survey of Pennsylvania.
DRAWN BY
LAURA LINTON

Note

Figures under names of towns denote elevation of R. R. Depots
Figures above wells, denote elevation of Well Mouths
Figures below wells, denote depth below ocean level
The top and bottom figures added, give depth of Well.

Formations

a Corniferous Limestone
b Bradford 3rd Sand
l Warren Oil Group
m Venango Group including Butler, Clarion and Venango Oil Sands
n Crawford Shales
o Conglomerate Measures including Oil on Slippery Rock and Mountain Sands
t Lower Productive Coal Measures
s Lower Barren Coal Measures
r Upper Coal Measures including "Pittsburg Coal Bed"
t Upper Barren
p Mahoning Sandstone

Alignment of Section

From Black Rock Erie Co. N.Y. to Pittsburg Pa. 175 Miles S. 20° W.
From Pittsburg to Dunkard Creek, Greene Co. Pa. 50 Miles S. 1° E.
Horizontal 7⁄10 Miles to inch = 40560 ft.
Scale Vertical 2000 ft to inch
Ratio, Horizontal to Vertical, about 20⁄1

The following table, compiled from those prepared by Mr. Carll, shows the elevation above tide-level, the fall, distance, and rate of fall per mile of the top of the third oil-sand in Warren, Venango, Clarion, and Butler counties. Dogtown is at the same level above tide-water as Clintonville, one mile northeast of Turkey City (see map III)·

Above tide.		Course.	Fall.	Miles.	Rate.
Feet.			*Feet.*		*Feet.*
	Along axis of Venango belt:				
1,008	Tidioute to—				
230	Clintonville along line of development		778	42.23	18.42
	Ditto, bee-line	S. 39° W.		39.50	19.70
	Along axis of Butler-Clarion belt:				
230	Dogtown to—				
−418	Herman station along line of development		648	29.83	21.72
	Ditto, bee-line	S. 27° W.		28.25	22.94
370	Shippenville to—				
−418	Herman station—				
1,008	Tidioute to		788	37.49	21.02
−418	Herman station (*)	S. 21° W.	1,426	62.00	23.00

* Reports, III, p. 144.

These figures show that the top of the third Venango oil-sand dips to the southwest in the 62 miles between Tidioute, in Warren county, and Herman station, in Butler county, at the average rate of 23 feet to the mile.

The first paying oil-well on the Butler-Clarion belt was obtained on the Allegheny river at Parker's landing in the fall of 1868, and operations spread out but a short distance from that point during the years 1869 and 1870.

In 1871 the somewhat unexpected measure of success attending the test wells, which were advancing toward the northeast into Clarion county, and also those toward the southwest into Butler county, led to developments in both these directions which resulted in pretty thoroughly outlining within the next three years the main or central belt.

Subsequently side lines of development were run, and the district was found to widen out in many places and to contain side belts and pools, with oil sometimes in the fourth sand, sometimes in the third, and in some localities even in rocks above the third sand, all of which aided very materially in augmenting the production. * * *

In 1874 the maximum development of this district was reached during the great fourth sand or "cross-belt" excitement. (*a*)

* * * * * * * *

At Parker's landing the oil came from the lowest member of the oil group, the representative of the Oil creek third sand, and so the rock was very properly called, not the fourth sand, but the third. In Clarion county, however, and likewise in Butler, the oil first obtained came from a rock higher in the series. But the drillers of the early wells did not notice the change from one horizon to another, and consequently supposed that they were still getting the oil from the Parker third sand. After the development had reached Modoc and Petrolia, it began to be suspected that there might be two oil horizons, instead of only one, and then commenced the experiment of deeper drilling at Petrolia and elsewhere, which finally resulted in the development of the "cross-belt", which was also called the "fourth-sand belt". (*b*)

* * * * * * * *

When Bradford first began to give signs of promise as an oil-field, the map of western Pennsylvania being consulted, the embryo development was found to be on a nearly direct continuation of the Clarion county oil belt. Immediately several transit lines were started by different parties and run through from the old to the new ground. Each surveyor had his own particular angle of deviation from the meridian to run by; and each one, as far as possible, carefully kept the exact bearing and location of his line a secret.

A statement was published at that time and much quoted as a proof of the unerring exactness of this method of tracing an oil belt, provided the bearing of the "lead" had been properly calculated. As the story went, a "belt-line expert" ran one of these lines 65 miles through an almost unbroken forest, employing an engineer who had never been over the country before, and who knew absolutely nothing about the work beyond the bald fact that he was traveling by a designated degree of the compass. Nevertheless the line thus run conducted its fortunate projector out of the woods, down the mountain side, into the valley of Tunangwant creek, to a station within a few feet of the largest well at that time known in the Bradford district. And this termination of the line was considered by many as a conclusive proof that all the lands through which that line passed were "on the oil belt".

The profile section (Plate VII) and the vertical section (Plate VIII) have been prepared for the purpose of exhibiting the fallacy of such views, and to enable the reader to see at a glance what some of the fundamental features of the sedimentary structure of the oil region especially are.

The profile section (Plate VII) follows a line upon the map drawn from Black Rock, on the Niagara river, in Erie county, New York, to Pittsburgh, and thence to Dunkard creek oil-field, in Dunkard township, Greene county, Pennsylvania, close to the West Virginia state line. From Black Rock to Pittsburgh the bearing of this line is S. 20° W.—distance about 175 miles. From Pittsburgh to Dunkard creek its bearing is S. 3° E.—distance 50 miles.

Starting at Black Rock, the line crosses the foot of lake Erie and strikes the southeasterly shore at Lakeview, in Erie county, New York. Thence it runs through, or very near to, the following places: Jamestown, New York; Youngsville, on Broken Straw creek, in Warren county, Pennsylvania; Tidioute, on the Allegheny river, in Warren county; President, on the Allegheny river, in Venango county; Foxburg, on the Allegheny, in Clarion county; Parker's Landing, on the Allegheny, in Armstrong county; and Petrolia, Millerstown, and Great Belt City (or Summit), in Butler county. Thus it may be said to follow the Butler oil belt very nearly along its line of best development.

It is evident that, as this alignment of the profile section coincides geographically so nearly with the trend of the Butler and Venango oil-sands, there can be no trouble in properly locating upon it the Venango oil-sand group.

The Warren oil development, however, lies some 8 miles to the east-southeast of our line, and the Bradford oil development some 30 miles from it, in the same direction.

a Reports, III, p. 146, § 336 and 337.

b *Ibid.*, p. 147, § 340.

Now, it is a remarkable and important fact that in no boring in Pennsylvania has the Warren group of oil-rocks (unmistakably developed) been seen directly beneath the Venango group. It is equally a fact that in no boring has the Bradford "third" sand been seen directly below the Warren group. In other words, we have not a single direct oil-well measurement between these several groups, and therefore we must trust to some pretty nice and difficult calculations when we try to determine the thickness of these intervals; that is, when we attempt to place the Warren and the Bradford oil-rocks in their proper places in our profile section. But whatever inaccuracies of detail may thus creep into the section, it will still suffice to show the relative positions of such oil horizons as have been profitably worked in different parts of the country. It will certainly demonstrate the folly of drilling on so-called belt lines, run from one producing district to another, regardless of the age or equivalence of the rocks to be connected.

* * * * * * * *

The lowest horizon in our country from which oil in paying quantities has been obtained is that of the corniferous limestone formation, the home of the Canadian oil.

This rock can be unmistakably identified at Black Rock, in New York; and therefore Black Rock has been selected as the northern end of our profile section (Plate VII). The next and only other point at which the elevation of the corniferous limestone can be fixed is in the Coburn gas-well, at Fredonia, Chautauqua county, New York, for in our own state, as far as is known, it has never been reached by the deepest borings.

The average pitch of the corniferous limestone toward the southwest can be calculated from its elevation at Black Rock and at Fredonia, allowing us to judge approximately of the thickness of the measures between it and the Venango oil group. At Black Rock, as shown by the quotations below, the exact thickness of the rock is not known. We have assumed the top to lie about 52 feet above the surface of lake Erie, or 625 feet above ocean level, which cannot be far wrong. In the Coburn well at Fredonia it is said to have been struck at a depth of 1,050 feet, which (the elevation of the well mouth being 735 feet) puts it 315 feet below ocean level at that place. The distance from Black Rock to Fredonia is about 38 miles in a direction S. 35° W., and this gives an average slope or dip of about 25 feet per mile. But along our section line (S. 20° W.) the average dip of the limestone ought to be stronger than 25 feet per mile, because the line runs more nearly in the direction of the line of greatest dip, as calculated from other strata which admit of more accurate tracing; and this inference is strengthened by the fact that no limestone is reported in Jonathan Watson's deep well near Titusville.

The distance from Black Rock to Watson's well is about 100 miles; direction, S. 26° W.; elevation of well mouth, 1,290 feet above ocean; depth of well, 3,553 feet. On an average slope of 25 feet per mile the limestone should have been found at 1,875 feet below ocean level, or 3,165 feet from the surface; but as no limestone was seen in the well, we must conclude either that it is absent in that locality (which is hardly probable), or that it has a greater average dip slope than 25 feet per mile in that direction. As the well stopped at 2,263 feet below ocean level, an average of 29 feet per mile would put the limestone at 2,275 feet, or 12 feet beneath the well. A hard rock was reported, however, just as the utmost limit of drilling cable forced a suspension of the work at a depth of 3,553 feet from the surface. A number of other deep wells are shown on the profile, but it will be seen that none of them have gone deep enough to reach the corniferous limestone. The Watson well is not only the deepest boring ever made in western Pennsylvania, but it is also deeper geologically than any other. It is greatly to be regretted, therefore, that so little can be known of its history.

A person unacquainted with the laws of sedimentary deposition and with the methods of preparing a profile section might inadvertently be led to suppose, from an examination of the profile section (Plate VII), that the different strata represented there spread out continuously and universally in every direction under the oil regions; that a well failing to produce oil in the Venango group might be put down 400 or 500 feet deeper and pump oil from the Warren group, and then 500 feet deeper and renew itself in the Bradford "third" sand; but such has not been the experience of oil producers. The several groups of oil-producing rocks are locally well defined under certain areas; but they have their geographical as well as their geological limits, and as far as at present known the geographical limit of one group never overlaps that of another. If we take a map and outline upon it the limits of the Smith's Ferry and Slippery Rock oil-producing district, and then the Butler, Clarion, and Venango, and then the Warren, and then the Bradford, we shall see that each has its own particular locus, and that the different districts are separated from one another by areas (of greater or less extent) which have been pretty thoroughly tested by the drill and proven to be unproductive. It must have been true in all ages that every deposit of sandstone in one locality must have been represented by contemporaneous deposits of shales in other localities. Hence it happens that in tracing rocks long distances the sandstones disappear and shales come in at the same geological horizon. It may not then be presumed that each particular sandstone, or its oil, will be found in every locality where its horizon can be pierced by the drill, or that a measured section of the rocks in one place can be precisely duplicated in detail in another. The vertical section (Plate VIII) is intended to show that oil has been produced from ten or twelve different geological horizons in the earth's crust, ranging through a thickness of about 4,500 feet of sedimentary strata; and the most skillful oil producer, the most expert geologist, cannot tell how many other oil horizons may exist at intermediate depths beneath the surface (*i. e.*, in the scale of the formations), but which, being good only within certain geographical limits, have as yet escaped the oil-miner's drill (see Plate V).

VERTICAL SECTION.

SUMMARY SKETCH OF THE FORMATIONS EXHIBITED IN THE VERTICAL SECTION (Plate VIII).—This generalized section extends from the surface rocks in the upper barren coal series of Greene county, Pennsylvania, down to the corniferous limestone, the Canadian oil-rock, and will enable any one to distinguish and locate the several oil horizons thus far discovered and profitably worked in these measures. It is in fact an enlarged representation of the features presented in the profile section. (Plate VII.)

GROUP No. 1.

UPPER BARREN COAL MEASURES B.—"Greene county group;" thickness, 600 feet.

VERTICAL RANGE.—From surface to top of Washington upper limestone.

COMPOSITION.—Shales, sandstones, thin beds of limestone, and coal.

EXPOSURES.—The highlands of central and southwestern Greene county, Pennsylvania.

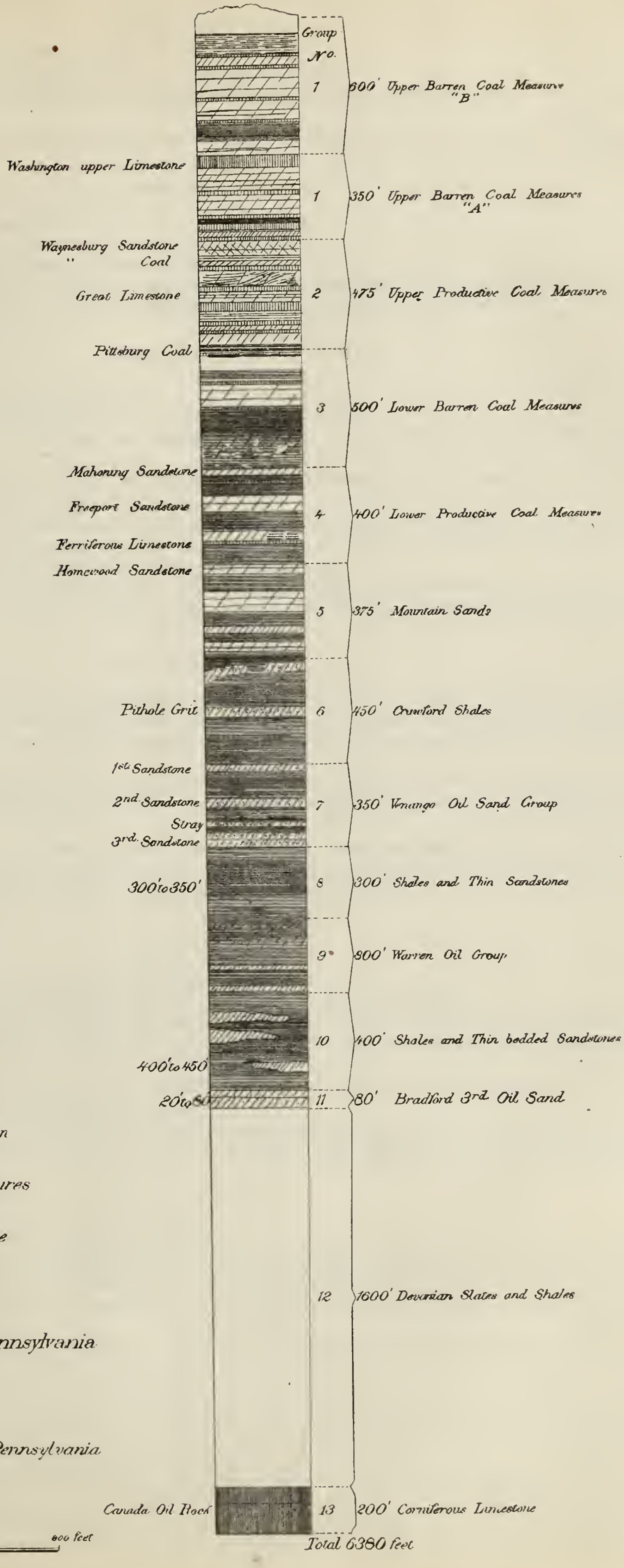
AUTHORITY.—Professors J. J. Stevenson, Report K, p. 35, and White and Fontaine, Report PP, Pennsylvania Survey.

UPPER BARREN COAL MEASURES A.—"Washington county group;" thickness, 350 feet.

VERTICAL RANGE.—From top of Washington upper limestone to top of Waynesburg sandstone.

COMPOSITION.—Shales, sandstones, limestones, and thin beds of coal; but carrying also the "Washington coal-bed", from 7 to 10 feet thick. In Washington county six beds of limestone compose about one-third of the mass, but in Greene the limestones are thin and less frequent.

EXPOSURES.—In the highlands of Washington and Greene counties (see Report K, p. 44, Pennsylvania Survey).



Generalized Vertical Section
from the top of the
Upper Barren Coal Measures
down to the
Corniferous Limestone
to show the various
Oil Horizons
of
Canada, New York and Pennsylvania
Compiled by
J. F. Carl
for the
Second Geological Survey of Pennsylvania
drawn by
Laura Linton
Scale
400 300 200 100 0 400 800 feet

GROUP No. 2.

Upper productive coal measures.—Thickness, 475 feet.

Vertical range.—From top of Waynesburg sandstone to base of Pittsburgh coal.

Composition.—Shales and sandstones, with three thick bands of limestone and several thick coal-beds, of which the Waynesburg and the Pittsburgh are the most important.

Exposures.—Throughout Washington, Greene, and Allegheny counties (see detailed section in Professor Stevenson's Report K, p. 57).

GROUP No. 3.

Lower barren coal measures.—Thickness, 500 feet.

Vertical range.—From base of Pittsburgh coal to top of Mahoning sandstone.

Composition.—Shales and sandstones, with some thin beds of limestone and coal.

Exposures.—Partially seen in Washington and Allegheny counties and in the highlands of southern Butler, but better developed in Beaver county, where Mr. White's detailed section of these measures was taken (see Report K, pp. 75, 76).

GROUP No. 4.

Lower productive coal measures.—Thickness, 400 feet.

Vertical range.—From top of Mahoning sandstone to top of conglomerate No. XII.

Composition.—Sandstones and shales, with several good and persistent coal seams and two important beds of limestone—the "Freeport" and the "Ferriferous".

Exposures.—This series is exposed over a large extent of country in Butler, Armstrong, Clarion, Beaver, Lawrence, and Venango counties (see Mr. Chance's detailed section, Report V, p. 16).

Professor Stevenson states (Report K, p. 392) that the Mahoning sandstone, the top member of this group, is the central and principal oil-bearing rock of the three sands found in oil-wells on Dunkard creek, Greene county. It also appears to be an oil-producing rock in Westmoreland county, where a number of oil- and salt-wells have been sunk through it.

The Ferriferous limestone of this group is the great limestone of Butler, Armstrong, and Clarion counties, and the oil-miner's "key-rock" in sinking oil-wells in these sections. It is from 5 to 25 feet in thickness, and lies from 30 to 80 feet above the Homewood sandstone, the top member of conglomerate No. XII.

GROUP No. 5.

Mountain sand series, including the Pottsville conglomerate No. XII, and probably in some localities some of the sandstones belonging to the Upper Pocono sandstone No. X (No. XI being either thin or wanting); thickness from 350 to 425 feet, say 375 feet.

Vertical range.—From top of Homewood sandstone to the base of the Olean-Garland-Ohio conglomerate, or second-mountain sand of the Venango oil-wells.

Composition.—A group of variable conglomerates and sandstones interstratified with shales and inclosing sporadic beds of iron-ore and coal, two of the coal-beds, the Mercer and Sharon, being of great importance. It also carries in some localities two thin bands of limestone (the Mercer Upper and Lower).

Exposures.—In the highlands of Mercer, southern Crawford, Venango, Forest, Warren, and McKean counties. The lower members of this group produce heavy oil at Smith's Ferry, in Beaver county, and on Slippery Rock creek, in Lawrence county, and the upper conglomerate is said to be the source of some oil in Kentucky (also in Johnson county, Kentucky).

GROUP No. 6.

Crawford shales.—Thickness, from 400 to 500 feet, say 450 feet.

Vertical range.—From the base of the mountain-sand series to the top of the Venango oil group.

Composition.—Shales and slates, inclosing the Pithole grit, near the center of the mass. In some localities 100 feet or more of the lower part is composed of red shale; in others no red appears. The upper part in some sections contains quite important beds of sandstone.

Exposures.—Only favorably seen in cliffs bordering the streams in parts of Forest, Venango, Mercer, Crawford, Warren, and McKean counties, its northern outcrop being always obscured by drift.

The horizon of the Pithole grit appears to furnish the light-gravity amber oil at Smith's Ferry and Ohioville, in Beaver county, with traces of the same on Slippery Rock creek, in Lawrence county. It also probably yields the heavy lubricating oil of the Mecca district, in Trumbull county, Ohio.

GROUP No. 7.

Venango oil group.—Thickness, from 300 to 375 feet, say 350 feet.

Vertical range.—From the top of the first oil-sand (the "second sand" of the driller in Butler county) to the bottom of the third oil-sand (called the "fourth sand" in Butler, Armstrong, and Clarion, and the "fifth sand" in some parts of Venango county).

Composition.—A group of variable sandstones, in some places conglomeritic, and locally divided into several members by irregular beds of slates and shales, some of which are red.

Exposures.—These rocks, as a group, lie with a remarkable uniformity of slope and general structure in a comparatively narrow belt, from Herman station, in Butler county, to Tidioute, in Warren county. They make no conspicuous outcrops to the northwest, but appear to lose their sandy characteristics before reaching the surface.

At Tidioute the deep gorges of Dennis run and the Allegheny river expose the *first and second oil-sands*, and as far up as Warren it is quite probable that we see the upper portion of the group exposed in the river hills. These are the only localities where a portion of the group in even an approximately normal condition may be seen above water-level. Its horizon is cut through by many of the ravines of McKean county, but it has there become so changed in its physical aspects that it disappears or becomes unrecognizable when the proper range for its outcrop is reached. These are the oil-sands of Tidioute and Colorado, Warren county; Fagundus, Forest county; Church run and Titusville, Crawford county; and of all the well-known oil centers in Venango, Clarion, Armstrong, and Butler counties. They produce oil in different localities from the members of the group, ranging from 30° to 52° in gravity, and varying greatly in color:

green oil from the third sand on Oil creek; black oil from the stray sand at Pleasantville; amber oil from the second sand in many places; and dark, heavy gravity oil from the first sand at Franklin. There are also occasional local deposits of oil, shading from a light straw color to almost a jet black.

GROUP No. 8.

Interval between the Venango and the Warren oil group.—Thickness, 300+ feet.

Vertical range.—From the base of the Venango third oil-sand to the top of the Warren oil group.

Composition.—Soft shale of a bluish-gray color, but containing some beds of green, purple, and red, with irregular bands of thin-bedded bluish-gray sandstones.

The wells at Warren, even when favorably located, do not pass through the Venango group in its normal condition, nor do the wells on the Venango belt, when sunk to the proper depth, as many of them have been, find the Warren oil shales and sands with oil; consequently no direct measurement of this interval can be made in oil-wells. In the section we have assigned a thickness to the mass which places the Venango and Warren oil groups as near as may be in their proper relative positions vertically at Warren.

GROUP No. 9.

Warren oil group.—Thickness, about 300 feet.

Vertical range and composition.—This group may be viewed as including the so-called second, third, and fourth sands of Warren; but its composition is so variable in different parts of the district that it does not afford any persistent bands of sandstone by which to define either its upper or its lower limit. At North Warren the upper part is shaly, and the largest wells, it is claimed, flowed from these shales, while others got their oil from the "third sand". At Warren the "second sand" is fairly developed, but the oil generally comes in the "third sand". At Stoneham a lower sand, the "fourth", produces the oil. Thus the North Warren shales are represented at Stoneham by more sandy measures which contain no oil, and the Stoneham "fourth sand" is poorly developed at North Warren, and is unproductive. The group, then, may be said to extend from the top of the North Warren shales to the bottom of the Stoneham sandstone, covering an interval, as nearly as may be calculated, of about 300 feet.

GROUP No. 10.

Interval between the Warren oil group and the Bradford "third sand".—Thickness, from 400 to 450 feet, say 400 feet.

Vertical range.—From the Stoneham oil-sand to the Bradford oil-sand ("third").

Composition.—Slates and shales, generally of a bluish color, but sometimes inclined to red or brown, interstratified with thin bands of bluish-gray micaceous flaggy sandstones. The sand pumpings show this interval to be very fossiliferous.

Similar difficulties are encountered in estimating the thickness of this group to those mentioned in No. 8. A large number of wells have been sunk between Bradford and Warren, but the rocks are so variable in composition and the well records have been so imperfectly kept that no completely satisfactory identification of the rocks of the Warren oil group, with their equivalents at Bradford, or of the Bradford "third sand", with its corresponding stratum at Warren, can yet be made. The interval between the two oil horizons, however, appears to be in the neighborhood of 400 feet, as above given. This interval holds the Bradford "second sand", which has yielded oil in many of the McKean county wells, and also the sandy shale horizon producing "slush oil" along the Tuna valley.

GROUP No. 11.

Bradford third sand.—Thickness, from 20 to 80 feet.

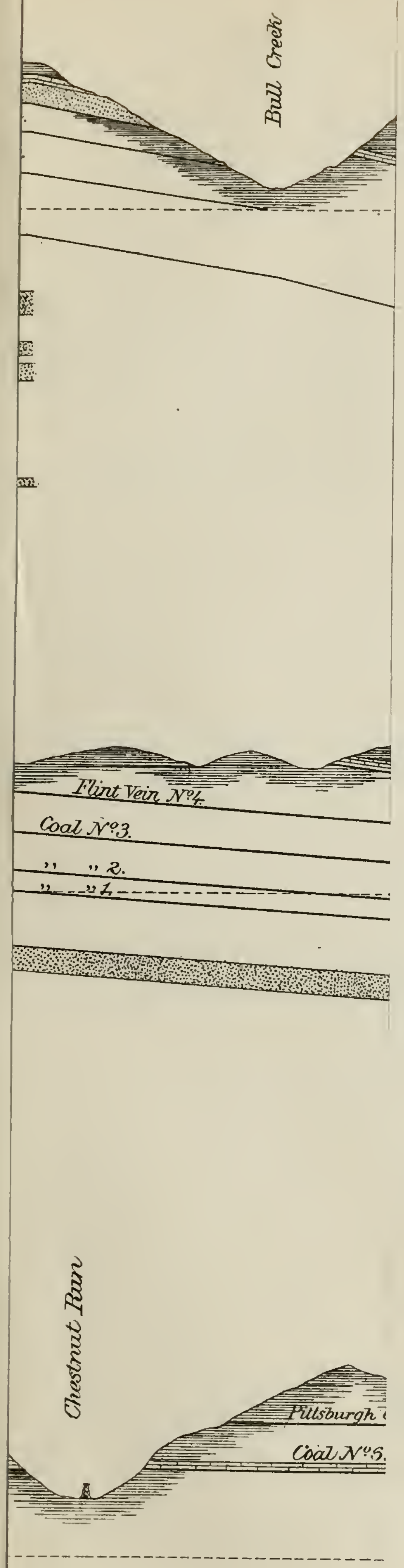
Composition.—A fine-grained, light to dark brown sandstone, containing pebbles the size of pin-heads in some localities, while in others it is little more than a sandy shale. It appears to be rather thin and irregularly bedded, is frequently interstratified with thin layers of gray, slaty sandstone, and contains many fossil shells and fish bones. The constitutional peculiarities of the rock, its color, its composition, and its structure, insure its ready recognition by the driller in any locality where he may find it in even an approximately normal condition. But this rock, like all others, has its geographical limits, outside of which its geological horizon can only be traced by the exercise of the greatest of care and the best of judgment in keeping and studying the well records.

It is seldom, however, that good records of wells on debatable territory are kept. The well-owner always starts the drill on the presumption that the oil-rock will be found. He calculates in his own way its approximate depth from the surface, and makes a contract to drill so many feet. Confident of success, he urges on the drill, making no particular note of the character of the upper rocks; but when the supposed horizon of the sand is reached, and the evidences of its presence do not appear as anticipated, he discovers, too late, that he has nothing to check by to ascertain whether the oil-rock is actually wanting or only so changed in character as to be scarcely recognizable, or whether there may not have been some mistake in calculating its position in the well. Thus it often happens that wells of this class are abandoned after drilling in doubt for a few days without having been sunk to the proper depth, while others are carried on down many feet below the horizon of the sand they are in quest of, and much valuable information is lost which a little prudent foresight might have secured.

The Bradford "third sand" may be satisfactorily located in the Wilcox wells, near the southerly line of McKean county. At Tidioute, in Warren county, 35 miles nearly due west from these wells, the base of the Venango group is well defined. Between these two points, the nearest geographical approximation that can at present be made, both groups evidently undergo rapid and radical changes in composition, and the well records are vague and unreliable; hence no absolute determination of the thickness of the mass of shales lying between the two groups can here be made.

Somewhat better facilities are afforded for a study of these measures by carefully tracing the rocks from Tidioute to Warren (15 miles), and then from Warren to Bradford (25 miles); but even along these lines the structure is so obscure that mistaken identifications are quite likely to be made.

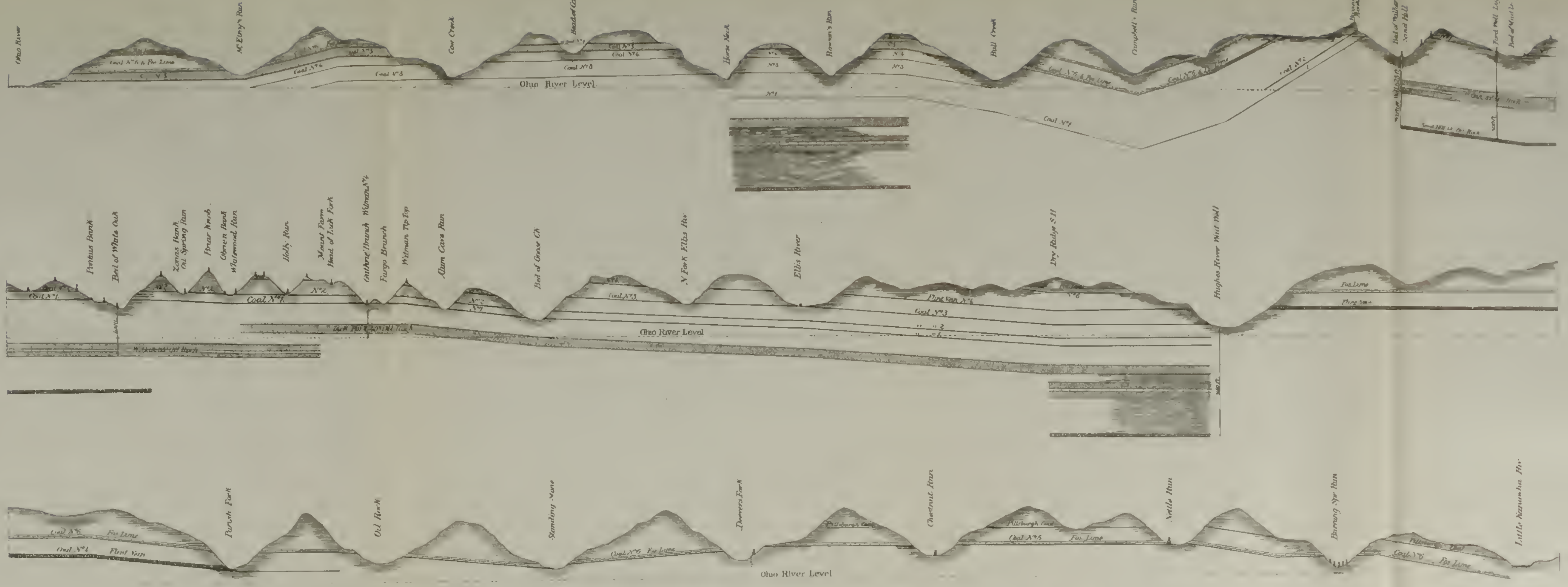
These facts are stated to explain why there is yet some uncertainty regarding the thickness of the vertical interval between the Venango oil group and Bradford "third sand". The figures cannot differ materially, however, from those given in the vertical section, Plate VIII.



VER to LITTLE

600 ft. to 1 inch.

Plate III.

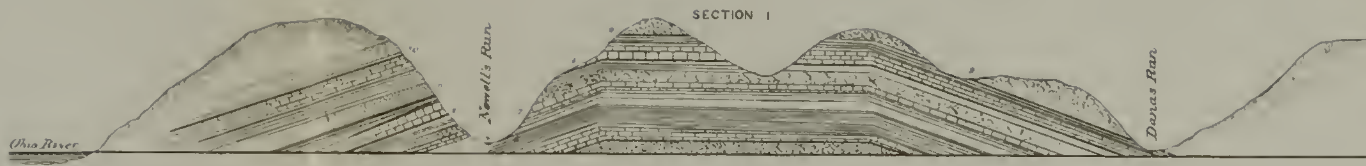


Profile through AXIS of W.Va. ANTICLINAL from OHIO RIVER to LITTLE KANAWHA RIVER.

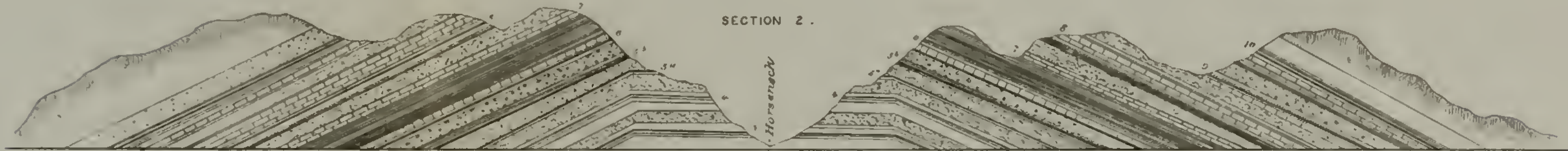
By W.F. Minshall.

Horizontal Scale 1 mile to 2 inches Vertical Scale 600 ft. to 1 inch.

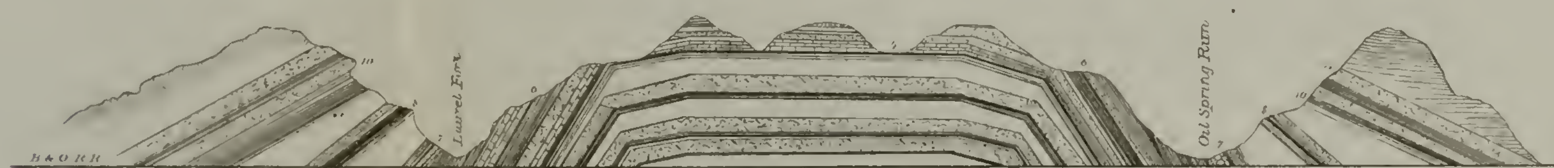
Plate IV.



SECTION ON THE OHIO RIVER ABOVE MARIETTA.



SECTION AT HORSE-NECK, WEST VIRGINIA.



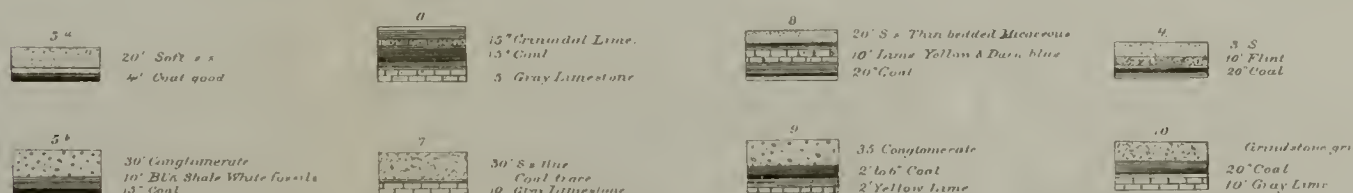
SECTION BETWEEN LAUREL FORK JUNCTION AND PETROLEUM,

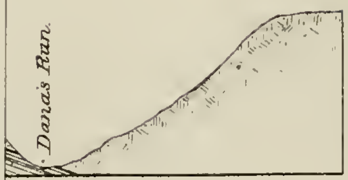
WEST VIRGINIA.

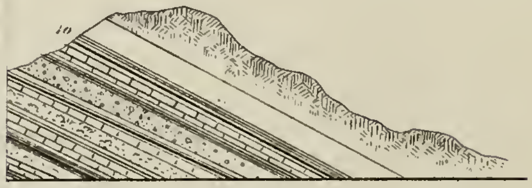
ON THE BALTIMORE & OHIO R R

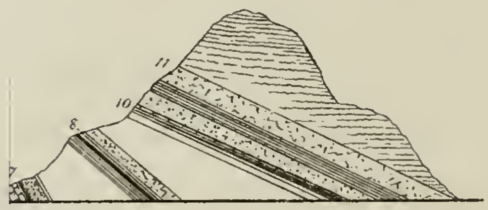
No 1 to No 5 inclusive, Lower Coal Measures
No 6 Crinoidal Lime Middle Barren Measures
No 7. Pomeroy Pittsburg, Upper Measures

No 8 Great Limestone
No 9, Macksburg, Waynesburg
No 10. Gray Lime and Thin Coal Upper Barren Meas.
No 11 Constitution Stone, Grindstone grit etc



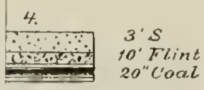


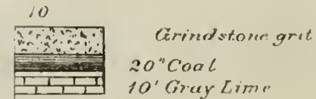




JM.

. Great Limestone.
, Macksburg, Waynesburg.
). Gray Lime and Thin Coal. Upper Barren Meas.
/. Constitution Stone, Grindstone grit etc.





GROUP No. 12.

INTERVAL BETWEEN THE BRADFORD "THIRD SAND" AND THE CORNIFEROUS LIMESTONE, commencing in the Chemung and including the Portage and Hamilton groups of the New York geological survey. Thickness, 1,600+ feet.

COMPOSITION.—In the imperfect records of wells that have been sunk into these measures in various parts of the country we simply find recorded "shales, slates, and soapstone, with occasional sand shells". The upper part for 200 or 300 feet appears to contain considerable sandy material, and some of these sand-beds produce oil along the Tuna valley, in the vicinity of Limestone, Cattaraugus county, New York. Below this the drillings show principally slate and soft-mud rocks. No important bands of sandstone and no oil have been reported.

The thickness of this interval must be left questionable for reasons previously stated. We have no means of tracing the corniferous limestone south of Fredonia, New York, except approximately by its slope.

The distance from Fredonia to Bradford is about 48 miles; direction about south 45° east. A dip of 20 feet to the mile would be required to place the limestone at Bradford as shown in our section.

GROUP No. 13.

THE CORNIFEROUS LIMESTONE, probably shown in the vertical section, Plate VIII, in conjunction with the ONONDAGA LIMESTONE.—The composition of this group has already been referred to in the quotations given from *Geology of New York*. It is the oil-producing rock of the Canadian oil regions, but at Fredonia, New York, yields neither oil nor gas. We may not presume, therefore, that it will ever be found to be an important oil horizon in Pennsylvania, and even if it should prove to be productive here the great depth at which it lies beneath the surface must be a very serious obstacle in the way of its development. (*a*)

An illustration of the persistence of the Venango oil group as a geological formation is found in the circumstances attending the drilling of well No. 1 by the Brady's Bend Iron Works Company in 1865. Professor J. P. Lesley was asked to give an opinion upon the probable depth at which oil would be reached on their property, and as he was familiar with the rocks of that locality, and had made a careful study of their dip and superposition, he readily made the computation and reported that "if the Venango sand extended under ground as far as Brady's bend it ought to lie at 1,100 feet beneath water-level". The well was drilled and struck the oil stratum at 1,120 feet.

During 1877 the so-called grasshopper excitement occurred near Titusville, occasioned by the discovery of oil in a layer of superficial gravel beneath a sheet of clay. The wells were simple pits or shafts, from which the oil and water were pumped. The area was comprised within a few acres, but was quite productive for a time, yielding several hundred barrels of oil. The oil evidently arose from deeper sources with water, and accumulated in the gravel beneath the impervious crust of clay.

The geology of the "West Virginia Oil Break" has been recently subjected to a very careful study by F. W. Minshall, esq., of Parkersburg, West Virginia. Mr. Minshall has been connected with the petroleum industry of this region for many years, and has carefully collated the records of many wells located along the line of development in Ohio and West Virginia. His sections are considered accurate by those most familiar with the facts and best qualified to judge of their value, and are found to conform strictly to such observations as I was able to make during a hurried trip through the region. I introduce here in illustration a series of sections compiled and drawn by Mr. Minshall and generously placed at my disposal for use in this report. The section on Plate iii extends along the axis of the anticlinal from the Ohio river opposite Newport, in Washington county, Ohio, to the Little Kanawha river, in Wirt county, West Virginia. Section 1 on Plate IV crosses section on Plate III at a point on or near the Ohio river in Washington county, Ohio. Section 2, Plate IV, crosses section on Plate III at Horseneck, Pleasants county, West Virginia. Section 3, Plate IV, crosses section on Plate III on the line of the Baltimore and Ohio railroad from Laurel Fork Junction to Petroleum, Wood county, West Virginia. Plate V is a vertical section of the rocks yielding petroleum along the anticlinal. Map IV shows the territory that has produced oil in the White Oak district which lies along the anticlinal between Goose creek and Walker's creek, Wood county, West Virginia.

The following description of the occurrence of the formations along the line of the White Oak anticlinal is taken from a series of articles published by Mr. Minshall in the summer of 1881 in the *State Journal* at Parkersburg, West Virginia:

In Wood, Pleasants, Ritchie, and Wirt counties the rocks, from the river level to the tops of the hills, belong to the upper barren measures, excepting only the line of territory known as the "oil break", which passes through these counties. Although we are very nearly in the center of the great Allegheny coal basin, we have no workable veins of coal above drainage in the above-named counties. The Allegheny basin is a veritable basin in form, which not only contains many valuable veins of coal, ore, and potter's clay, but also vast quantities of natural gas, petroleum, and brine.

On account of our situation near the center of the Allegheny basin, all the mineral wealth of its rocks is sunk beneath the river level. Here at Parkersburg, barely above the river, may be seen a thin vein of coal with an underlying vein of gray limestone. This we will call coal No. 11, and take it for our dividing line between the upper barren and upper productive coal measures. From the river to the top of fort Boreman, at the mouth of the Little Kanawha, we have an exposure of about 300 feet of the upper barrens. Examining them in detail, we will find them composed of alternate layers of red shale and compact, fine-grained sand rocks. The sand rock is of considerable value as a building-stone, being the same ledge as that which is extensively quarried between Belpre and Harmar, some parts of it furnishing grindstone grit and others the "Constitution" building-stone.

If, commencing at our coal No. 11 (see Plate V), we should sink a well, we would pass through the following strata: At about 150 feet we would reach the level of coal No. 10, the first vein of the upper productive measures, which has a thickness of from 4 to 6 feet

a Reports, III, p. 156.

on Duck creek, in Washington county, Ohio ; at 250 feet we should find coal No. 9, the limestone vein of Duck creek, and the equivalent of the Sewickly vein of Pennsylvania; at 350 feet we should pass the level of coal No. 8, the Federal creek vein of Athens county, Ohio, and the Pittsburgh vein of Pennsylvania, which is the last vein of the upper productive coal measures.

We next pass through the red and variegated shales of the lower barren measures, until at 500 feet we reach the crinoidal limestone. At 600 feet we will pass into a soft, pebbly sand rock, the first oil-rock of Cow run, Ohio; at 700 feet we should strike a hard, black, flinty limestone, several feet of very black shale, with white fossil shells and coal No. 7; at 730 feet, coal No. 6; at 800 feet, coal No. 5; at 850 feet another cherty limestone, probably the "Putnam hill" of the Ohio survey; at 880 feet, coal No. 4; at 900 feet we find another soft pebbly sand rock, the second oil-rock of Cow run, Ohio; at 1,000 feet, coal No. 3; at 1,070 feet, coal No. 2; at 1,200 feet coal No. 1; and at 1,300 feet, the top of the carboniferous conglomerate—the oil-rock of Lick fork and Tate run, in the White Oak district. (*a*)

These are the rocks through which we ought to pass in our Parkersburg wells. This prediction is based upon the fact that the uplift of the "oil break" brings this whole series of rocks above the level of the Ohio river in such a way that any one can examine them at his leisure and verify the intervals for himself.

Going back to our coal No. 11, with its underlying gray limestone, we will cross over into Ohio and trace it up the river on that side. At Marietta we find it coming up from the bed of the Muskingum near the "Children's Home". Keeping back from the Ohio river about two miles we see it in the bed of Duck creek at the old Robinson mill, in the bed of the little Muskingum at the mouth of Long run. We find very little change in the level of the stratum we are tracing till we are opposite the mouth of Cow creek. Here we find it gradually rising higher above the river as we go up the Ohio until, at the mouth of Newell run, on the Ohio side, we find it at the summit of the hill. Since it is evident that a farther rise will take it away from us, we must take our barometer and measure down the hill to coal No. 10; but instead of the 6-foot vein of Duck creek, we have here barely 2 feet; in fact, this vein thins rapidly southward from the maximum thickness at the upper line of Washington county, Ohio.

Having at the mouth of Newell's run substituted coal No. 10 for No. 11, we will go a little farther east until, opposite the mouth of French creek, we find coal No. 10 on the summit of mount Dudley. On mount Dudley we are standing on the axis of the anticlinal called the West Virginia oil break. Measuring down the face of the hill 100 feet from coal No. 10, we find coal No. 9, the limestone vein. Measuring again from coal No. 9 down the hill about 100 feet, we will find the proper horizon of coal No. 8, the Pittsburgh vein of Pennsylvania and the Pomeroy vein of Ohio. It is true that we will not succeed in finding any coal at this point; the overlying sand rock, a little fire-clay, and the underlying gray limestone are all we can find here; but before reaching the end of our journey we will find the coal putting in an appearance. The horizon of this vein is exposed from the Ohio river to the Little Kanawha along the axis of this anticlinal for a distance of about 30 miles, in which distance the coal increases from nothing to 20 inches. Measuring down from No. 8,150 feet, we will find the crinoidal limestone of the lower barren measures lying about 40 feet above low-water mark. To show that we are upon the axis of the anticlinal, we will trace the limestone eastward along the face of the hill. For about a quarter of a mile we will find it running level, then dipping gradually to the east, until it disappears beneath the river. Returning, we trace it westward, and, after running level for the same distance, it dips to the west and goes under the river. At no other point in Washington county can this limestone be seen. (See Section 1, Plate IV.)

Having thus satisfied ourselves that we have reached the axis of "the break", our purpose is to follow this axis to the point where it crosses the Little Kanawha above Burning Springs, West Virginia.

Starting out from mount Dudley (see Plate III), we bear several degrees west of south, cross the Ohio a little below French creek, in Pleasants county, cross McElroy run at Ned Hammett's, and strike the north hillside of Cow creek near the residence of Hugh McTaggart, esq. In a hollow north of the house, and about on a level with it, we find the crinoidal limestone. Continuing our course, but bearing more nearly south, we cross Cow creek below the old "Willard" mill, the head of Calf creek, near William Nash's, and reach a high point on the north side of Horseneck. On the very summit, by searching carefully, we will find, as though it had been placed there for our especial benefit, the crinoidal limestone about 580 feet above the river. To satisfy ourselves that the anticlinal maintains its form, and that we are still upon its axis, we trace the limestone westward till it dips beneath the bed of Calf creek, near the new school-house, and eastward into the bed of Sled fork of Cow creek; and we notice that the dip is getting steeper on the sides as the axis rises, but no signs of faulting or displacement of the strata are to be found. (See Section 2, Plate IV.) Our crinoidal limestone, which was 500 feet below the river at Parkersburg, is now 580 feet above, having risen 1,080 feet, and, like coal No. 11, having reached the summit of the highest hills, will soon be beyond our reach if the axis continues to rise. We will therefore take the precaution to measure down to some of the lower strata. One hundred feet below the crinoidal lime we find another massive sand rock similar to the one which lies over coal No. 10. Like that, it is a true conglomerate, with layers of quartz pebbles somewhat similar and whiter than those of No. 10. It is the first oil-sand of Cow run and Macksburg, in Washington county, of Buck run, in Morgan county, and of Federal creek, in Athens county, Ohio, easily identified by the interval being about 100 feet in all of the above-named places. At its outcrop at the head of Calf creek it forms a bold ledge, which at one point is broken into huge cubical blocks of about 30 feet in thickness, forming a "rock city" similar to the one near Olean, in New York.

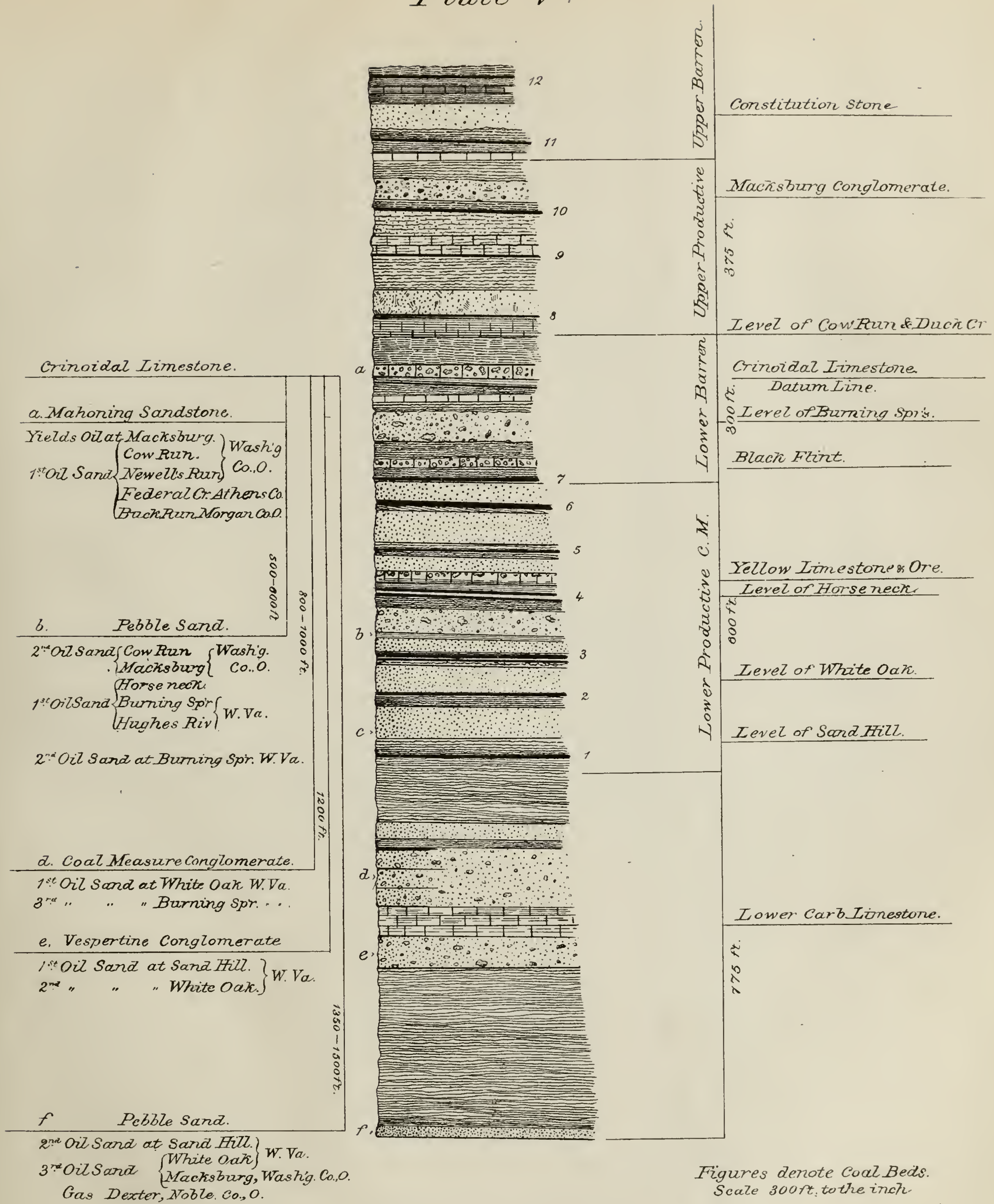
Below this sand rock, and about 200 feet below the crinoidal lime, we find coal No. 7. Although the coal is only 18 inches thick, this vein becomes interesting because of its surroundings. Just over the coal is a stratum of very black shale, about 10 feet thick, filled with fossil shells. Over the shells is a black, flinty limestone, which we will find increasing in thickness southward until it becomes the well-known flint vein of Hughes river and Flint run.

From Horseneck we resume our course, crossing Bull creek near the celebrated mineral well of Judge Borland. In the bed of the run, a short distance above Judge Borland's well, we find the crinoidal limestone. Careful inspection shows us that we are still following the axis of the anticlinal, and that it has come down on the south of Horseneck even more rapidly than it had risen on the north. This will, when examined, prove to be a regular dip along the axial line, without any indications of faulting, and the dip continues until the gray limestone of No. 8 is brought down to the bed of the run; then the dip is suddenly reversed, and the axis rises again to the southward. From this point to Sand hill, on Walker's creek, the rise is very rapid, bringing to the surface in regular succession the rocks above described down to the yellow limestone. This we follow in its upward course till it reaches the top of the high point near the Saint Ronan wells of White Oak district. Looking around us from this vantage-ground we will notice that although the distant hills preserve their graceful outlines the surrounding hills are mostly cone-shaped peaks, bristling with an unnatural kind of timber, the rig timber of the oil-seeker. In prosperous times, when clouds of smoke were pouring forth from hundreds of sooty craters and the clang of tools rivaled the din of old Vulcan and his cyclopic helpers, some genius, in a moment of inspiration, christened the place Volcano.

On the top of the high peak near Saint Ronan's well we will examine the limestone, which lies within 25 feet of the summit. We have assumed this vein to be the equivalent of the "Putnam hill" vein of the Ohio survey; it is also the only vein we will find which might be taken to represent the "Ferriferous limestone" of Pennsylvania; it lies here a few feet above coal No. 4. Examining the

a Also of Johnson county, Kentucky.

Plate V.



VERTICAL SECTION

OF WHITE OAK ANTICLINAL

WEST VIRGINIA.

Compiled by F. W. Minshall, Marietta O.

MAP IV.


MAP
OF THE
VOLCANO OIL REGION
OF
WEST VIRGINIA
SHOWING
THE DEVELOPMENTS UP TO THE YEAR
1882
VOLCANIC
OIL &
COAL CO.
WOOD COUNTY PETROLEUM CO.
LAUREL FORK
OIL &
COAL CO
WEST VA. OIL & OIL LAND COMPANY
TURNPIRE
PETROLEUM
Jacob Fangs
Elliott
E. L. Gale
Rathgate Farm
George Rutherford
Dr Wm Marbury
Laurel Fork Junction
W C Stiles Jr
Arnold Br
Cannon Br
N
W
E
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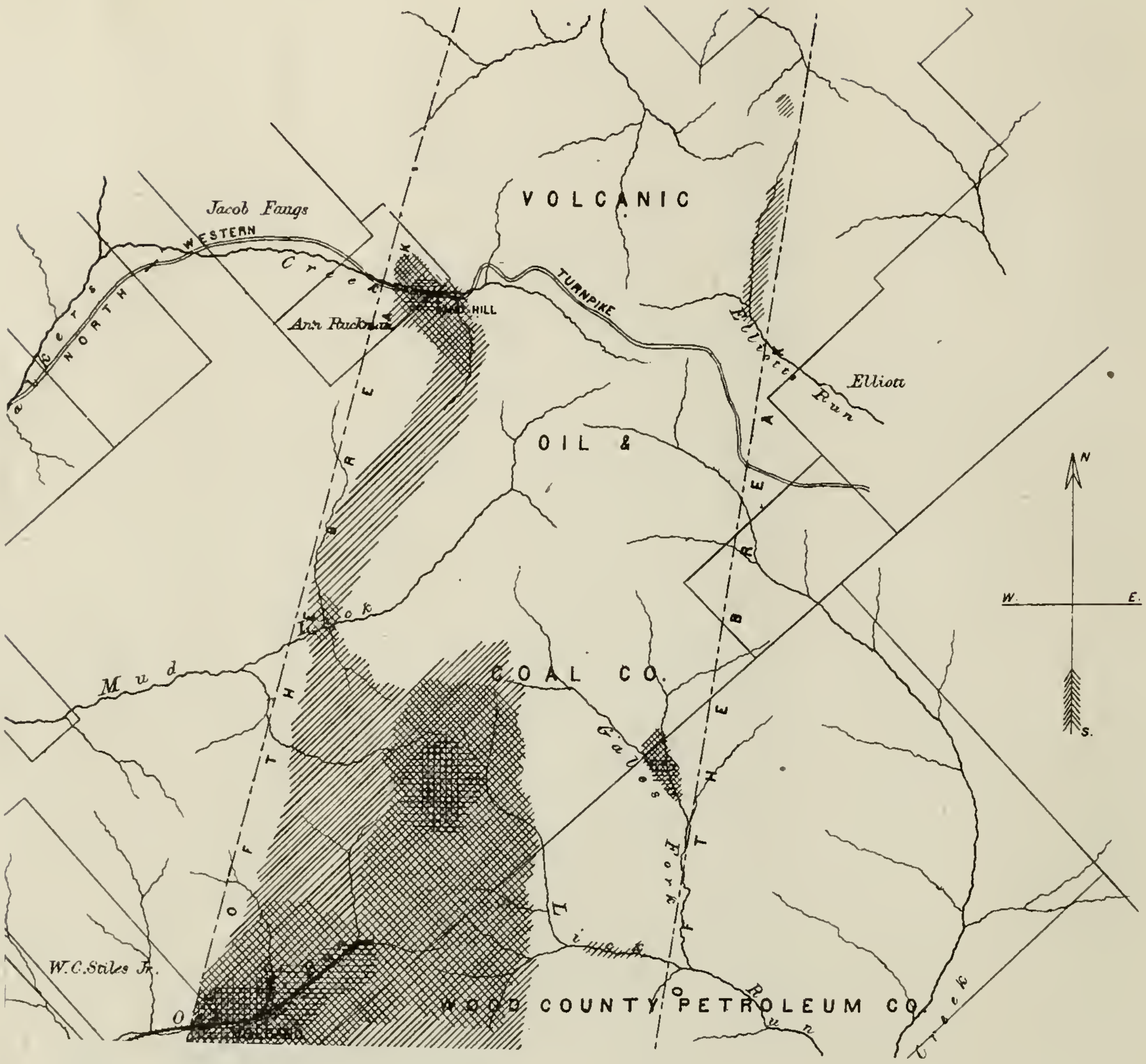
MAP IV.



VOLCANIC
OIL &
COAL CO.
WOOD COUNTY PETROLEUM CO.
Jacob Fangs
NORTH WESTERN
TURNPIKE
Elliott
Elliotts Run
Mud
W.C. Stiles Jr.

structure of the vein, we find that it is deposited in large, round bowlders, from one to three feet in diameter. The upper layers are heavily charged with iron, showing, when exposed to the weather, a very rusty yellow. A peculiar feature of the ore-bearing bowlders is their formation in regular concentric layers. If one of them be broken through the center you may see, from center to circumference, the rings as regular as the rings of a cross-section of a tree. As the bowlder becomes oxidized these rings peel off successively, leaving its form unchanged. The identification of this vein as the equivalent of the "Ferriferous" would be of great value to us for the purpose of comparing the geological level of our oil-bearing rocks with those of Pennsylvania.

Resuming our measurements from this limestone downward we will find, 30 feet below it, coal No. 4; 160 feet below the lime, coal No. 3; and 230 feet below the lime, coal No. 2. With this vein is a hard, black slate, about a foot thick, which is always piled in masses around the mouth of the mine, and is sometimes called "bone-coal". These measurements can be made to the best advantage by going down the south side of the hill into the hollow on the Saint Ronan lease, in which coal No. 2 is mined, all the points of exposure being on the central axis and as nearly vertical as is possible to find them.

In order to get a good exposure of the limestone for examination, we came beyond the highest point in the axial line. We will therefore retrace our steps for about a mile northward. This will bring us to "Sand hill". Here we find coal No. 2 about 170 feet above Walker's creek, and the horizon of coal No. 1 about 40 feet above the bed of the stream. In lieu of coal we shall have to content ourselves with the thick bed of fire-clay, which is a persistent accompaniment of it in Ohio. Assuming the bed of Walker's creek at this point to be 250 feet above the level of the Ohio river, we have, from the river level up to coal No. 1, 290 feet, plus interval from coal No. 1 to yellow limestone, 360 feet, plus interval from yellow lime to crinoidal lime, 350 feet, plus interval from crinoidal lime to coal No. 11, 350 feet, equal to 1,500 feet, the total amount of uplift to the highest point. Add to this 500 feet of the upper barren measures, which may be seen in the surrounding hills, and deduct the 250 feet which lie below the bed of Walker's creek, and we have 1,750 feet of coal-measure rocks fairly exposed within an area of a few miles, which any student of geology may study at his leisure.

We will now go back to Sand hill and resume our journey southward (see Map IV). Crossing White Oak fork of Walker's creek above Volcano, we keep along the ridge, with Coal Bank run and Rogers gulch on our right and Oil Spring run, with its branches, on our left, till we come to the dividing ridge between Lick fork and Tate run; here we halt and look around us. From Sand hill to this point we have passed through the center of the White Oak producing territory, a strip along the central axis of the break about four miles long and one mile wide, on which there are something like 600 wells now working. The southern end, at which we have stopped, is now the busiest part.

Glancing down at our feet we will see that we are standing upon a soft, yellow sand, filled with pebbles about the size of a pea; some of them have a delicate blue tinge, but most of them are of a very clear white, almost translucent. This is the second oil-sand of Cow run, Ohio, from which a single well has produced $200,000 worth of oil.

* * * * * * * * *

Here there is just as much attention paid to the oil-rock proper as in any other territory. The only peculiar feature about the territory is the fact of its being located on the crest of a well-marked anticlinal, and whether you will find an accumulation of gas, oil, or water in the rock depends upon the comparative level of the point at which you strike a fissure. The statement which Professor Stevenson makes concerning the form of the "break" at Hughes' river along the Staunton pike is accurate and true for the whole length of the line; "there is no evidence of faulting on either side. The succession from the inner portion of the abruptly-tilted strata outward to the horizontal strata is unbroken and perfectly clear. Within the 'break' the rocks are almost horizontal and not much broken. They describe a flattened anticlinal". That this statement is true of the most disturbed portion of the whole line we may see for ourselves. Starting from the point at which we halted, we will go down on to Lick fork. From this point the stream runs nearly west to its junction with Laurel fork. About 40 feet above the bed of the stream we will find coal No. 2 lying horizontal. Following it westward down the run, we find that it soon begins to dip gradually, and in the course of a few rods comes down to the bed of the stream. Just before it disappears we see that it is beginning to dip at a much steeper angle, but shows no displacement. As we continue down the stream we find that we are passing over the upturned edges of the strata, but everything is in its proper place. Coal No. 3, the pebbly sand-rock that lies above it, the yellow limestone, the black flint, the crinoidal limestone, and the gray limestone of the Pittsburgh vein, each is seen in its legitimate position, the intervals being comparatively the same as when we measured them vertically. Laurel fork, from the mouth of the Lick fork to the Baltimore and Ohio railroad, runs very nearly parallel with the axis of the break. Placing the compass upon the upturned edge of the crinoidal limestone, where it is exposed in the bed of the run, we see that it runs straight as a line S. 10° W. Being only 18 inches in thickness, it serves us admirably as an indicator of the course of the break. The black flint and the gray limestone, when tried by the compass, show the same course. From the mouth of Lick fork to the railroad this gray limestone of the upper productive coal group may be traced. Standing almost vertically, it crosses the railroad in the bed of the stream between Laurel junction and the first cut to the west. In this cut the double vein of coal No. 9 of the upper measures shows dipping at a sharp angle to the west. At the west end of this cut the dip becomes more gradual, but continues until the rocks of the upper coal group, including our No. 11, are brought down to the level of the railroad. If we should go eastward from Laurel junction to Petroleum we should find the same state of facts existing that we have just enumerated; in the beds of Oil Spring run and Goose creek all of our well-known rocks, from coal No. 2 to coal No. 11, dipping to the east complete the symmetry of the anticlinal. (See Section 3, Plate IV.)

From the head of Lick fork the axis of the break commences to dip southward. Following the axial line we cross the northwestern branch of the Baltimore and Ohio railroad about midway between Laurel junction and Petroleum, cross the head of Ellis run and along Dry ridge to William Sharpneck's, on the north side of Hughes' river. Near the school-house on Dry ridge may be seen a fine exposure of the crinoidal limestone, here 350 feet above the bed of Hughes' river, showing a southern declination of about 580 feet between this point and the highest point of the axis at Sand Hill. About 200 feet below the crinoidal limestone is the flint vein. The same black shale, filled with white fossil shells, that underlies it at Horseneck is found here, affording a sure means of identification.

Resuming our journey southward, we cross Hughes' river near the old Walton Wait well, climb the steep hill on the south side, and keep along the ridge with the waters of Island run on the west and of Flint run on the east, until we come to the head of Wilson's branch of Parish fork. From Dry ridge to this point we find the crinoidal limestone lying about level; from this point it commences to dip southward. We follow the course of Wilson's branch down to within a few rods of the old Parmenter well, then over the ridge, cross Parish fork above the residence of Mr. Fred. Bailey, cross oil-rock near the old "Orchard" well and the main branch of Standing Stone creek at the Fisher farm. Here we find the crinoidal limestone just 30 feet above the bed of the creek. Total southern dip from Sand hill to Standing Stone, 850 feet. The dip has now been sufficient to bring the soft pebbly sandstone which lies over coal No. 10 into the hills. Going westward down the creek, we may see this ledge of rock, about 40 feet thick, running like a wall from the bed of the stream to the top of the hill.

At Standing Stone the south dip is reversed and the axis rises. Following the line, we cross Dever's fork at David Dever's, where we find the crinoidal limestone 150 feet higher than at the Fisher farm. Continuing our course, we cross the head of Chestnut run, keep along the ridge with the headwaters of Upper Burning Spring run to the east and Nettle run to the west of us, and strike Lower Burning

Spring run near the Newberger and Braidon well. Here we find the crinoidal limestone 125 feet above the Little Kanawha river, making 800 feet in geological level between this point and the head of Walker's creek at Sand hill. The bed of the stream at Walker's creek being 200 feet higher than the bed of the Little Kanawha makes the difference in drilling for any given rock about 600 feet. * * *

At Burning Springs the axis again commences to dip southward, and at the point where it crosses the Little Kanawha, a short distance above the mouth of Spring creek, the crinoidal limestone is 60 feet below the bed of the river.

Our investigation shows that the White Oak anticlinal or "oil break" is a fold or wrinkle in the bottom of the great trough called the "Allegheny coal basin", extending from a point about 4 miles north of the Ohio river to a point about the same distance south of the Little Kanawha at Burning Springs; that there are undulations in the axial line which divide the line into three sections, which, had there been no erosion of the surface, would have presented three peaks of different altitudes; that of Horseneck would have been about 500 feet higher than that of Burning Springs, and that of White Oak about 300 feet higher than that of Horseneck, and the summit of the White Oak peak would have been about 2,000 feet above the level of the Ohio river. Under each of these peaks the rocks lie in the form of a table, say four miles long and from three-fourths to one mile wide. From the ends and sides of these tables the rocks dip at certain angles. Taken as a whole, the rocks form inverted basins, with flat bottoms and sloping sides. In these inverted basins nature for thousands of years had been collecting gases as the chemist collects them in inverted bottles over the pneumatic cistern. At Burning Springs the accumulation of gas became so large that it forced its way through the fissures of the overlying rocks to the surface, forming a natural gas-spring, which often became ignited and burned for days on the surface of the water through which it was escaping.

All of the work done in this region prior to 1864 was done without recognizing the fact that the territory was confined to the crest of an anticlinal, and large sums of money were expended in the purchase of territory and drilling of wells along the margins of other streams in the neighborhood. The operators also remained ignorant of the fact that two of the producing rocks of White Oak lay beneath the conglomerate. The escape of the gas at the summit of the other inverted basins drew the attention of operators to Horseneck and White Oak (from Burning Springs). About the year 1865 General A. J. Warner and Professor E. B. Andrews, of Marietta, became interested in White Oak territory, and these gentlemen soon began to draw geological inferences which led to an abandonment of the old policy of following the beds of the streams and to a recognition of the fact that the oil was confined to the crest of an anticlinal; hence the White Oak section, and that alone, has been thoroughly and systematically worked. After it had been clearly recognized that the oil territory was confined to the crest of the anticlinal, it was somewhat hastily inferred that the crest would be valuable territory for its entire length, and many test wells were drilled on the strength of this inference. These test wells showed such a large percentage of failures that, three years ago, the writer undertook to account for them by making a careful level along the entire length of the axis. The undulations of the rocks shown by the profile (Plate III), taken in connection with the known laws of hydrostatic pressure, satisfactorily account for the failures, and show that part of the crest of the anticlinal is filled with an accumulation of water, and also what part must contain the accumulation of oil and gas.

Taking into consideration our position in the trough of the Allegheny basin, and the fact that on all sides of us the conglomerate is filled with brine, as on the Allegheny river above, at Pomeroy and Charleston below, on the Big Muskingum to the west, and the head of the Little Kanawha to the east, at all of which points it lies at a higher level than it does in the counties through which we have passed, we may safely conclude that the productive oil territory of West Virginia must be confined to the summit of the anticlinals or local rolls similar to the White Oak line.

The question has been raised by some of the Pennsylvania geologists as to whether rocks lying below sea level can be expected to contain an accumulation of oil. In 1878 the writer drilled a well at Dexter, Noble county, Ohio, in which he struck a sand-rock about 700 feet below sea-level, containing a large accumulation of dry gas, and in the succeeding year George Rice, esq., obtained at Macksburg, Ohio, a flowing well from the same rock at the same level. The writer's well at Dever's fork, in Wirt county, also contains a large accumulation of gas and some oil in the Vespertine sandstone 300 feet below sea-level. This question is mentioned here because all of the Pennsylvania oil-bearing sands, if here at all, would lie several hundred feet below tide-water, even on the crest of our White Oak anticlinal.

CONCLUSIONS.

I have quoted Mr. Minshall's work in great detail, and have introduced all of his sections, for the purpose of showing the facts from which his conclusions have been drawn. His facts were ascertained after many a mile of tramping and careful barometrical measurement; a work far more laborious and valuable than that of collating the records of wells, which, though sometimes correct, are more often defective through ignorance or inattention. Mr. Carll has tramped over the hills and through the forests of northwestern Pennsylvania to gain personal knowledge of the region, and his work has high value in the eyes of the oil producers. Both Mr. Minshall and Mr. Carll have learned the geology of petroleum at the edge of the drill, barometer in hand, both of them seeing and handling what they describe.

Assuming that Messrs. Hunt, Carll, and Minshall have observed correctly and stated their observations correctly, petroleum occurs in crevices only to a limited and unimportant extent. It occurs saturating porous strata and overlying superficial gravels; it occurs beneath the crowns of anticlinals in Canada and West Virginia, and does not occur in Pennsylvania; but in the latter region it occurs saturating the porous portions of formations that lie far beneath the influence of the superficial erosion, like sand-bars in a flowing stream or detritus on a beach. These formations or deposits, taken as whole members of the geological series, lie conformably with the inclosing rocks, and slope gently toward the southwest. The Bradford field in particular resembles a sheet of coarse-grained sandstone, 100 square miles in extent by from 20 to 80 feet deep, lying with its southwestern edge deepest and submerged in salt water and its northeastern edge highest and filled with gas under an extremely high pressure.

It is further to be concluded that, from whatever source the petroleum may have originally issued, it now saturates porous strata, not of any particular geological age, but runs through a vast accumulation of sediments from the oldest to the newest rocks, in Pennsylvania and West Virginia embracing all of the rocks between the Lower Devonian and the Upper Carboniferous.

Chapter IV.—THE CHEMISTRY OF PETROLEUM.

Section 1.—THE CHEMISTRY OF CRUDE PETROLEUM.

The wide distribution of bitumen in nature has already been noticed. As early as 1823 the Hon. George Knox called attention to its prevalence in rocks and minerals, and showed that, along with lithia and fluorine, it had been overlooked in their analyses. (*a*) The following year Vauquelin published a notice, with an analysis of the bitumen contained in the sulphur of Sicily. (*b*) In 1837 Boussingault published the results of an examination of the bitumen of Pechelbronn and other bitumens of southern Europe, which for many years was considered a classic upon the subject. (*c*) In 1853, Dr. C. Völckel examined the asphalt of the Val de Travers. (*d*) These analyses of solid bitumens were mainly attempts to determine the constitution of these materials by ultimate analysis, and were very valuable at the time they were made.

The first research upon fluid bitumen or petroleum was made by Vauquelin in 1817 upon the naphtha of Amiano, which at that time was used in street lamps in the small towns of the duchy of Parma. (*e*) In 1857, Engelbach examined the petroleum sand of the Luneberger heath, in Holstein, which has lately been attracting so much attention; (*f*) and Warren de la Rue and Hugo Miller worked on several tons of Rangoon tar or Burmese petroleum, and distilled the oil with steam at 100° C. and with steam superheated to 200° C., and examined the distillate. (*g*)

American petroleum was examined by Professor Benjamin Silliman, sen., in 1833, (*h*) and by Professor B. Silliman, jr., in 1855, who published his results in his celebrated report on the petroleum of Venango county. (*i*) Since petroleum became an article of commerce innumerable examinations from all parts of the world have been made for technical purposes. These examinations have been chiefly made with reference to determining the amount of distillate available for illuminating purposes. In the earlier period of the commercial production it was assumed that petroleums from different localities were identical, except in specific gravity, and that therefore the distillate of the same specific gravity possessed the same properties. Professor B. Silliman, jr., and myself examined the petroleums of California; (*j*) H. St. Claire Deville and others those of Java, Pennsylvania, and Russia; (*k*) Raveset examined Trinidad pitch, (*l*) Waller the petroleum of Santo Domingo, (*m*) and Silvestri the petroleum-like constituents of the lavas of Etna. (*n*) The distillations essential to these analyses were often conducted in an ordinary glass retort, or with an alembic. Of the two, the alembic is very much to be preferred, as its use prevents the cracking of the oils. In 1868 Dr. H. Letheby contrived an apparatus for this purpose, which is described in the *London Journal of Gas Lighting*, xii, 653. In 1866 Dr. John Attfield published a description of another, (*o*) and the following year I described an apparatus of my own invention for the technical analysis of petroleums or solid bitumens, either with or without pressure. (*p*)

The ultimate analysis of petroleum early showed it to consist of carbon and hydrogen. It was for a long time assumed that crude petroleum contained an equal number of atoms of these elements, but my own examination of Californian and other petroleums in 1867 and 1868 (*q*) showed that the first named variety contained from 0.5645 to 1.1095 per cent. of nitrogen; that Mecca (Ohio) oil contained 0.230 per cent., and oil from the Cumberland well, West Virginia, 0.54 per cent. of the same element. Determinations of the hydrogen and carbon in several samples of petroleum showed that the proportion of carbon increases with the density. The following table shows the percentage of composition of the several different varieties: (*r*)

	Hydrogen.	Carbon.	Nitrogen.
Scioto well, West Virginia	12.929	86.622	....
Cumberland well, West Virginia	13.359	85.200	0.5400
Mecca, Ohio	13.071	86.816	0.2300
Hayward Petroleum Company, California	11.819	86.934	1.1095
Pico spring, California	....	....	1.0165
Cañada Laga, California	....	....	1.0855
Maltha, Ojai ranch, California	....	....	0.5645

a *Phil. Trans.*, 1823; *Phil. Jour.*, ix, 403; A. J. S. (1), xii, 147.
b *Ann. de Chim. et de Phys.* (2), xxv, 50.
c *Ibid.*, lxiv, 41; New Ed. *Phil. Jour.*, 1837.
d *Ann. der Chem. u. Pharm.*, lxxxvii, 139.
e *Ann. de Chim. et de Phys.* (2), iv, 314.
f *Ann. der Chem. u. Pharm.*, ciii, 1.
g *Phil. Mag.* (4), xiii, 512.
h *Am. Jour. Sci.* (1), xxiii, 97.
i *Am. C.*, ii, 18.
j A. J. S. (2), xxxix, 341; (2), II, xliii, 242; C. N., xvii, 257; *Geo. Surv. of Cal.:* Geology, ii, Appendix, p. 49.
k *L'A. S. et Ind.*, 1871, 146.
l *Jour. de l'E. au gas*, 1872; *A. Chem.*, ii, 316.
m *Am. Chem.*, ii, 220.
n *Gaz. Chim. Ital.*, vii, 1.
o *Chem. News*, xiv, 98.
p A. J. S. (2), xliv, 230; C. N., xvi, 199.
q *Rep. Geo. Surv. Cal.:* Geology, II, Appendix, pp. 84, 89.
r *Ibid.*, p. 89; *Am. Chem.*, vii, 327. The methods of analysis used to meet the peculiar difficulties presented by these substances is fully described in both the works referred to.—S. F. P.

Delesse notes 0.154 per cent. of nitrogen in elalerite and 0.256 per cent. in the bitumen from the pitch lake of Trinidad. (*a*)

O. Hesse has shown the presence of sulphur in Syrian and American asphalt to the amount of 8.78 and 10.85 per cent., respectively, and one sample of California petroleum examined by myself contained a sufficient amount of sulphur to form a deposit in the neck of the retort. It is well known that Canada petroleum contains sulphur, but the Pennsylvania and West Virginia oils are remarkably free from it. A qualitative test for sulphur in petroleum is described on page 181. An oil is described from the Kirghish steppe said to contain 1.87 per cent. of sulphur and to be purified with great difficulty. According to Mr. John Tunbridge, gold may be found in the ashes of crude petroleum and in the refuse of petroleum stills, and he is reported to have extracted $34 worth of gold from a ton of residuum, the source of which is not given. (*b*)

In general, it may be stated that the ultimate analysis of petroleum shows it to consist of carbon and hydrogen, with a very small proportion, in some instances, of nitrogen, sulphur, and perhaps oxygen. Metallic arsenic is said to condense in the goose-neck of the retorts in which the bituminous limestones of Lobsan are distilled. (*c*)

SECTION 2.—THE PROXIMATE ANALYSIS OF PETROLEUM.

In 1824 Reichenbach published his researches upon paraffine and eupion, (*d*) and ten years later published a paper upon petroleum or rock-oil; (*e*) and he appears to have been the first chemist who attempted a separation of the definite chemical compounds that are mixed together in petroleum and similar liquids. Further attempts were made at their separation by Laurent, (*f*) but, as might be expected, they were only partially successful, as the eupion and other liquids obtained by Reichenbach and Laurent were for the most part mixtures still.

In 1863 Schorlemmer, in England, and Pelouze and Cahours, in France, published researches upon American petroleum, which were really the first successful attempts to isolate any number of the constituents of this complex mixture of substances. Schorlemmer showed that American petroleum contained in the portion boiling below 120° C. the same hydrides as are obtained from the distillate from cannel coal, (*g*) but Pelouze and Cahours determined American petroleum to consist of the homologues of marsh-gas. The lowest determined by them was hydride of butyl, C_8H_{10}, which boils a little above 0° C., while the highest had a composition of $C_{30}H_{32}$. They considered paraffine a mixture of still higher terms, and regarded the small quantity of benzole and toluole alleged to have been obtained by Schorlemmer to have been due to destructive distillation of the petroleum. (*h*)

At the same time that the researches just mentioned were being carried on in Europe, C. M. Warren, alone and associated with F. H. Storer, was engaged on a similar research in this country. (*i*) The results obtained by them were published in 1865 and 1866, and while in the main confirmatory of those previously obtained, they were in many respects superior in point of definiteness and accuracy, from the fact that Warren used an apparatus for separating his material greatly superior to any hitherto employed. (*j*) In discussing the identity of the compounds obtained by himself and MM. Pelouze and Cahours, Warren remarks that he considers vapor density and analysis as corroborative evidence with boiling point; but aside from such evidence, he regards the superiority of his process of distillation as a paramount means of securing pure products for analysis, and therefore entitled to great consideration. (*k*)

Warren succeeded in isolating fourteen different liquids in quantities of several hundred cubic centimeters, and so pure that the whole quantity might be distilled from an ordinary tubulated retort within a range of temperature of 1° C. He was consequently enabled to determine their boiling points with great accuracy, and hence the difference in their boiling points, to analyze them and determine their vapor density and establish their formulæ. The composition assigned by him to the fourteen compounds is given in the following table:

FIRST SERIES.		SECOND SERIES.		THIRD SERIES (not completed).	
Formula.	Boiling point.	Formula.	Boiling point.	Formula.	Boiling point.
	Degrees.		*Degrees.*		*Degrees.*
C_4H_{10}	0.0 ?	C_4H_{10}	8–9	$C_{10}H_{20}$	174.9
C_5H_{12}	30.2	C_5H_{12}	37.0	$C_{11}H_{22}$	195.8
C_6H_{14}	61.3	C_6H_{14}	68.5	$C_{12}H_{24}$	216.2
C_7H_{16}	90.4	C_7H_{16}	98.1		
C_8H_{18}	119.5	C_8H_{18}	127.6		
C_9H_{20}	150.8				

a De l'Azote et des Matières dans l'Ecorce Terrestre. Paris, 1861, pp. 172, 173.
b J. F. I., cix, 175.
c Ann. des Mines (4), xix, 669.
d P. Mag. (2), i, 402.
e Schweig. Seid. Jour., ix, 133; *P. Jour.*, xvi, 376.
f Ann. Chim. et de Phys. (2), lxiv, 321.
g Proc. Manchester Phil. Soc., March 11, 1863; A. J. S. (2), xxxvi, 115.
h Ann. C. et P. (4), i, 5.
i Mem. Am. Acad., N. S., ix; *Am. J. Sci.* (2), xl and xli.
j Mem. Am. Acad., N. S., ix, 121; A. J. S. (2), xxxix, 327.
k A. J. S. (2), xlv, 262.

I have changed the atomic value of 12 given in Warren's memoir to that of carbon = 6, as at present used, in order that these formulæ may be more readily compared with others. Warren does not give the specific gravity of his compounds, nor does he give any hint regarding the relative proportions of these compounds in crude petroleum, and his work was qualitative as regards the crude oil. Messrs. Warren and Storer also examined Rangoon petroleum, with the following result:

	Deg. C.
Rutylene, $C_{10}H_{20}$, boiling at about	175
Margarylene, $C_{11}H_{22}$, boiling at about	195
Laurylene, $C_{12}H_{24}$, boiling at about	215
Cocinylene, $C_{13}H_{26}$, boiling at about	235
Naphthalin, $C_{10}H_8$	—

Also, probably, pelargonene = C_9H_{18}, boiling at about 155°, and members of one or both the series of hydrides (from American petroleum), it being a fair presumption that we have had in our hands hydrides of œnanthyl (C_7H_{16}), of capryl (C_8H_{18}), and of pelargonyl (C_9H_{20}). Our experiments also indicate the probable presence of xylole and isocumole. (*a*)

The latter, with naphthaline, are found in coal-tar.

It will be noted that these researches were had only upon the more volatile portions of the petroleum, without regard to the more dense portions with high boiling points, and that they established the fact that the more volatile portion of American petroleum contained principally the homologues of marsh-gas, with the general formula C_nH_{2n+2}, and also the homologues of olefiant gas, with the general formula C_nH_{2n}, and that the corresponding portion of Rangoon petroleum contained principally the homologues of olefiant gas, the benzole series, and probably some of the higher members of the marsh-gas series.

An examination of paraffine and its chemical relations showed that it was one of the higher homologues of marsh-gas, hence the English chemists have called the whole series paraffines, including the solid, liquid, and gaseous members.

During 1865 E. Ronalds isolated butyl hydride from American petroleum and described it as a liquid with a specific gravity of 0.600 at 32° F.; vapor density, 2.11, colorless, and of a sweet taste and agreeable odor. Alcohol of 98 per cent. dissolves from eleven to twelve times its volume. (*b*) The same year Tuttschew discovered the homologues of olefiant gas (C_nH_{2n}) in illuminating oil from Galician petroleum. (*c*)

Since 1865 up to 1880 the paraffines of American petroleum have been the subject of a vast amount of research, particularly by English chemists. Goldstein, (*d*) Stenhouse, (*e*) Odling, (*f*) Herman, (*g*) Morgan, and Schorlemmer (*h*) have all contributed to the mass of knowledge relating to this subject that is now the possession of chemists. Pre-eminent, however, among these investigators is the name of Schorlemmer; but it would be impossible to give here a *résumé* of his results that would be understood by the general reader; in fact, many of his most elaborate researches are of a purely scientific nature. His numerous papers will be found in the *Philosophic Transactions* and the *Journal of the Chemical Society.*

Very little has been done upon Canadian petroleum. Schorlemmer has shown that the benzole series is present in it. (*i*) Russian petroleum has been examined by Beilstein and Kurbatow (*j*), and they found that the more volatile products of Caucasian petroleum consist of the additive compounds of the benzole series, having a higher specific gravity for the same boiling point than the compounds constituting American petroleum and containing more carbon. Further experiments, undertaken to ascertain if American petroleum contained these bodies in small proportion, yielded negative results, all of the derived compounds showing the presence of the alcohol radicals (C_nH_{2n+2}), and not of benzole or its additive compounds. The relation which these additive compounds sustain to benzole may be inferred from the following formulæ:

Benzole	C_6H_6	Hexahydro benzole	C_6H_{12}
Toluole	C_7H_8	Hexahydro toluole	C_7H_{14}
Isoxylole	C_8H_{10}	Hexahydro isoxylole	C_8H_{16}

Schützenberger and Jonine having also examined Caucasian petroleum, (*k*) found a notable fraction of the light oil to consist of the isomers of ethylene (C_nH_{2n}). Their results confirm in a general way those obtained by MM. Beilstein and Kurbatow.

The liquids which form the heavier portions of petroleum, from which paraffine crystallizes, have not as yet been very fully examined. For some time it was questioned whether paraffine was a constituent of Pennsylvania petroleum, and those who maintained that it was not accounted for the fact that it sometimes crystallized from crude petroleum by assuming that such petroleum had been heated since it escaped from the wells. The phenomena attending the occurrence of petroleum in the Bradford district has, however, removed this question from all future

a *Mem. Am. Acad.*, ix.
b J. C. Soc. (2), iii, 54; *Bul. de la S. Chim.*, 1866, 135.
c *Jour. f. Prak. Chem.*, xciii, 394; *Bul. de la S. Chim.* 1865, ii, 229.
d J. C. S., xxxvi, 765; B. D. C. G. B., xii, 689.
e B. S. C. de P., 1878, 189; *Ann. der Chem.*, clxxxviii, 249.
f *Proc. Roy. Inst.*, viii, 16.
g Rep. B. A. A. S., 1875.
h J. C. Soc., xxviii, 3011.
i C. N., xi, 255; *Trans. Roy. Soc.* (5), xiv, 168.
j B. D. C. G. B., xiii, 1818 and 2028; A. J. S. (3), xxi, 67 and 137.
k B. D. C. G. B., 1880, 2428; Bul. S. C. P., 1880–2, 673.

controversy, as there paraffine is shown to be susceptible of fractional condensation, the extremely low temperature, consequent upon the removal of the enormous pressure, causing the more dense paraffines to condense in the pipes, leaving a large content of those with higher melting points still dissolved in the oil. It now appears to be firmly established that paraffine as at first isolated is not a homogeneous body, but a mixture of several homologous, perhaps isomeric, bodies having similar properties, but different boiling points. For the history of the discovery of paraffine and a description of the principal researches that have been conducted upon it, see the chapter on Paraffine in Part II of this work.

Recently the constituents of residuum have been made the subject of careful study. Professor Henry Morton, of the Stevens Institute of Technology, first called attention to these substances. Speaking of the distillation of "residuum" for the production of paraffine and lubricating oils, he says:

At the end of this operation, when the bottom of the still is already red-hot and some coke has been formed, there runs very slowly from the condenser a thick, yellow-brown tar, which is almost solid in cold weather, and in summer is only semi-fluid. * * * This thick tar, prior to 1873, was only used as a lubricant for the necks of rolls in rolling-mills, its great tenacity securing its adherence under the very unfavorable conditions to which it was there exposed. About March, 1873, however, Mr. John Truax, of Pittsburgh, wrote me as follows, referring to this tar: "Within a few months we have found a new use for it in the manufacture of a lubricating oil." * * * Returning to the production of what may be termed "thallene tar", I cannot do better than quote part of a letter received from Mr. Truax: "This material (referring to the thallene tar) drains or drips from the end of the pipe forming part of the condenser after all the tar has been distilled, and is in reality the product of the distillation of the petroleum pitch remaining in the still. Tar of petroleum (residuum), which we use exclusively, of gravity 20° Baumé (specific gravity 0.936) or thereabouts is distilled in cylindrical stills or retorts set vertically. These are 9 feet in diameter, and from 3 to 4 feet high. The condensation is effected in the usual manner. The stills are inclosed in brick work all around the sides, forming a flue, through which all the products of combustion in the furnace are obliged to pass. After firing the retorts, the first thing to come over is what we call 'light oil', though the man who made your kerosene would not call it so. This is from 35° to 40° Baumé, or 0.850 to 0.830 specific gravity, and we cut this off to return to the kerosene manufacturers. The balance of the charge begins now to fall rapidly in gravity (Baumé), and continues falling or getting heavier till the end of distillation, at which time the 'stuff' begins its exit and drops lazily into the trough. At this time the bottom of the still is red-hot, and has on it as residue from the charge a covering of coke from 8 to 10 inches thick. This coke is very porous and spongy, and very light, but is good for fuel, and makes little or no smoke." Farther on, in reference to the same thing, Mr. Truax says: "After several hours the stream, after having reached its maximum, begins to darken in color, and soon ceases altogether. Then your 'stuff' drags its slow length along. At this time everything is furiously hot; the bottom red-hot; the fire-brick of the furnace glowing like fire itself, and luminous as the fire, and the little oil remaining with the coke has a heat so great as to make its elements interchange in such a way as to make a large quantity of carbon unite with the very small quantity of hydrogen that is left behind the general exit so as to form your stuff. Several times in my experience, owing to some accidents, we have had to draw the fires before your stuff came over, and on opening the still or retort we found regular pitch, resembling in nearly every way pine-pitch or coal-tar (for roofing) pitch, except in absence of odor and taste, and in not being quite so plastic, but nevertheless a true pitch. Now the distillation of this pitch makes your stuff, that is, under favorable conditions."

I agree with Mr. Truax in his theory here expressed, that the thallene does not exist ready formed in the petroleum, or even in the petroleum tar, but is, like anthracine for example, a product of destructive distillation at something like a red heat. (*a*)

In a previous paper Professor Morton thus describes the preparation of thallene:

The crude tarry matter is well washed with benzine (petroleum naphtha), then with alcohol, and is lastly dissolved in benzole (coal-tar naphtha), filtered hot, and crystallized out on cooling. It is then obtained as a mass of very minute, needle-like crystals of a greenish-yellow color and pearly luster in the mass. * * * This I described under the name of Viridin in a paper read before the American Institute in New York, and drew attention to the very remarkable spectrum which its fluorescent light yielded, which resembled in a striking manner that of anthracine, while the crystalline form, solubilities, and fusing points of the two bodies were decidedly unlike. (*b*)

Hemillian also obtained petrocene in 1877 (J. C. S., xxxii, 867).

In 1879 MM. L. Preunier and R. David published a paper "Upon the nature of certain accessory products obtained in the industrial treatment of Pennsylvania petroleum", (*c*) which was followed and continued in another paper by M. Preunier, entitled "Study upon the unsaturated carbides derived from American petroleum". (*d*) In 1876 Dr. H. W. C. Tweddle exhibited at Philadelphia a greenish substance that he called "petrocene", from which he obtained a yellowish-green substance which he called "thallene". This was the raw material of this research, the few kilograms which were exhibited being obtained from 50,000 barrels of petroleum. The density of petrocene, that is to say, the crude material, is about 1.206. It was separated into lighter paraffines having a density of about 0.990, and heavier hydrocarbons of about 1.27, bromine and sulphuric acid separated from 5 to 15 per cent. of paraffine having a very high melting point, 70°, 80°, and 85° C., ordinary paraffine melting at 65° C. The unsaturated hydrocarbons, anthracene, phenanthrene, chrysene, chrysozene, and pyrene were recognized. Organic analysis showed a hydrocarbon containing from 88 to 96 per cent. of carbon, which is a larger percentage than is found in coal, even anthracite rarely attaining 95 per cent.

The following year (1880) MM. Preunier and Eug. Varenne published another paper "Upon the products contained in the cokes of petroleum". (*e*) They obtained a compound giving on analysis a mean of 97.9 per cent. of carbon, which corresponds to the theoretical compound $(C_{16}H_2)_n$, requiring 97.95 per cent. of carbon. These results, say the authors, conform perfectly to the general views of M. Berthelot, and confirm their own previous researches.

In 1873 MM. Le Bel and A. Muntz examined the black coloring matter of the semi-liquid asphalt of Pechelbronn (Bas. Rhin). (*f*) It is obtained in brittle, black scales from solution in carbon disulphide, and its coloring

a *Am. Chem.*, vii, 88.
b *Ibid.*, iii, 162, 106.
c B. S. C. P., xxxi, 158; B. D. C. G. B., 1879, 366.
d *Ibid.*, xxxi, 293; *Ibid.*, 1879, 843.
e *Ibid.*, xxxiii, 545, 567; *Ibid.*, 1880, 1141.
f B. S. C. P., xvii, 156.

power compares with aniline. They gave it the name "asphaltine", first given by Boussingault to a similar substance, and compare the analysis of this compound with that of a China bitumen as follows:

	Pechelbronn.	China.
Carbon	86.2	86.8
Hydrogen	8.8	8.7

As it is not volatile, the authors conclude that the asphalt is not a product of distillation.

In 1874 MM. Hell and Mendinger examined the organic acids of crude petroleum, (*a*) but the examination was not conducted in such a manner as to determine whether the acids obtained were an educt or a product of petroleum. They agitated the second running (specific gravity 0.857) of heavy Wallachian petroleum with caustic soda, and treated the flocculent precipitate with sulphuric acid. The result was a mixture of oily acids very difficult to separate, as they were decomposed by distillation. They finally succeeded in separating a colorless fluid, feebly acid, that produced a flocculent body with sodium or potassium, resembling soft soap, and they believed it belonged to a new series of fatty acids.

While these researches have been undertaken abroad, in this country Professor Samuel P. Sadtler, of the University of Pennsylvania, has been conducting a series of experiments upon petroleum and associated substances, with results that are embraced in the following extract from a letter dated Philadelphia, November 4, 1881, addressed to myself:

Classifying the subject under the three heads of: 1, Gaseous products accompanying crude petroleum; 2, Crude petroleum; and, 3, Solid products accompanying and derived from the petroleum, I started with the first. I made analyses of some ten lots of "natural gas" taken from wells in different parts of the oil-field, and representing different geological horizons as far as possible. As there was some doubt as to whether the results of eudiometric analysis could indicate the presence of the higher members of the paraffine series, I supplemented these analyses by a series of absorption tests made on the spot. Thus I passed a current of natural gas for a time through absolute alcohol, which, while it does not dissolve hydrogen, absorbs marsh-gas slightly, ethane, propane, and the higher hydrocarbons in increasing amount. The hermetically-sealed flasks of the alcohol were then examined in my laboratory, and the gases absorbed driven out by heat and collected over mercury and analyzed. They proved to be chiefly ethane and propane. I also passed a current of the gas through bromine, both pure and alcoholic, so as to absorb the olefines. On after examination in my laboratory, by neutralizing the free bromine with soda and diluting, I succeeded in separating out colorless oily drops of ethene dibromide, and presumably, though not certainly, propene dibromide. These results were read in part before the American Philosophical Society, and were reported in its proceedings. (*b*)

In the study of the liquid crude oils, after classifying the oils from the different geological horizons (with information supplied to me by Mr. John F. Carll), and noting gravities, color, and other physical properties, I proceeded to classify them by filtration (as far as possible in the cold) with animal charcoal and with mineral materials, like clay, alumina, etc. I did this with a view of examining chemically and miscroscopically the coloring impurities thus withdrawn. My results with these portions withdrawn by filtration are very incomplete; still I think they are largely made up of the members of the higher and more condensed hydrocarbon series, like anthracene, etc., and not simply amorphous carbon, as supposed by some chemists. In corroboration of this view I may say that in the crude oils picric acid will strike a deep blood-red color, like the color of its compound with anthracene, fluorine, etc., whereas in the yellow oil clarified in the cold by animal charcoal no such result is gotten. I also verified with a number of crude oils Schorlemmer's observation that olefines are present, capable of being withdrawn by bromine, and in small quantities members of the benzole series, capable of yielding nitro-derivatives like nitro-benzole and nitro-toluole. Indeed, taking several distinct fractions, gotten from Bradford oil, I got notable quantities, in the lightest fraction light-yellow nitro-benzole, and in the higher fractions reddish-yellow nitro-toluole and probably higher products. I also extracted paraffine from a number of the crude oils by mixing several volumes of ether with the oil and then chilling, when almost all the dissolved paraffine will separate and can be filtered off.

I commenced a study of the spent acid from a refinery in Titusville that had been running for several weeks exclusively on green oil from Petroleum Centre, hoping to get a class of sulpho-conjugated oils from it for study. I did not get further, however, than to separate them from the free sulphuric and sulphurous acids, and so have them yet.

Lastly, of the solid products which accompany petroleum I examined the paraffine of buttery or firmer consistence which separates out on the tubing or derrick-frames in Bradford oil-wells. This was dark in color, looking like the crude ozokerite of Galicia, but not so firm. It had all the characters of a paraffine mixture. I had also collected a whitish buttery mass from several flowing wells near Warren, Pennsylvania. This, on examination, proved to be a very perfect emulsion of oil and water, one which would stand for months, but separated into distinct layers of oil and water when warmed. I also took up for examination the solids gotten from Pennsylvania petroleum by pyrogenic formation. Of this character were petrocene and allied products first mentioned by Dr. Herbert Tweddle, and from which Professor Henry Morton extracted thallium. I had worked with it some months when Prunier published an account in the *Ann. de Chim. et Phys.* of an examination of the same substance. I then published in Remsen's *American Chemical Journal* an account of my results, showing the presence of several new hydrocarbons. (*c*)

In an article published by Professor Sadtler in 1876, he well shows the unsatisfactory condition in which the chemistry of petroleum stands at present. (*d*) After speaking of the various researches had up to that date, he says:

What was the material used for these investigations? Were the crude petroleums examined by these different authorities exactly the same, or if by chance they might have been, are they to be compared with all other petroleums now known? Those familiar with the crude oils as produced in the different sections of Venango, Clarion, and Butler counties, and very recently in Warren and McKean counties also, will know that these oils vary in color from a light amber to a dark black, and in gravity from 30° to 55° Baumé—from thick lubricating oils to nearly pure benzine. Moreover, they come from very different strata, or "sand rocks", as they are termed. * * *

It will thus be seen that if we wish to study the chemical composition of petroleum thoroughly we have a considerable body of material to choose from. This material must be carefully assorted, too, before any satisfactory study of the petroleum can be made. The great bulk of the crude petroleum that is sent to the refineries or is exported is shipped by the pipe-line companies, who have their network of pipes ramifying through whole districts, collecting the entire yield of a district and storing it in their immense tanks. To study such crude petroleums would be like analyzing the sweepings of a mineral cabinet.

a B. D. C. G. B., vii, 1216. *b* P. Am. P. S., xviii, 44. *c* *Am. Chem. Jour.*, i, 30. *d* *Am. Chem.*, vii, 181.

With perhaps a few exceptions, these remarks apply as forcibly to the work that has been done upon all other petroleums as to those of Pennsylvania.

The various attempts to produce by synthetic processes the oils that constitute petroleum will be noticed in detail when treating the chemical theories regarding its origin. They may be briefly stated as follows: Commencing in 1876 with Berthelot's synthesis of these liquids through the reaction of alkali metals, calcium, carbonate, and steam, we next have, in 1871, Byasson's successful experiments with steam, carbonic acid, and iron at a white heat; then, in 1877, Friedel and Craft's synthesis through the action of chloride of aluminum; then the same and the following year the reaction produced by M. Clœz upon carbides of iron and manganese by diluted sulphuric acid and boiling water; and finally, in 1878, Landolph's complex synthesis through the action of fluoborates. (*a*) M. Adolph Wurtz has shown that hydride of amyl (found in petroleum) and other hydrocarbons can be produced by the action of zinc ethyl on iodide of allyl. (*b*)

These oils have also been produced by the destructive distillation of the animal fats through the use of superheated steam. Warren and Storer fractionated the distillate from a lime soap of menhaden oil and obtained the members of the paraffine series, the homologues of olefiant gas, and the benzole group. (*c*) Cahours and Demarcay fractionated an oil boiling below 100° C., obtained by distilling fats by superheated steam, and found it contained pentane, hexane, and heptane. Another oil having a higher boiling point contained heptane, octane, nonane, decane, undecane, and a small quantity of dodecane, and probably cetane (hexdecane), all members of the paraffine series. (*d*)

SECTION 3.—THE CHEMICAL ACTION OF REAGENTS UPON PETROLEUM AND ITS PRODUCTS.

In attempting to classify the work that properly falls into this section I find it in a very fragmentary condition. The residues from gas works where petroleum is used have been studied by S. Cabot, jr., and he found them to contain the benzole compounds, but neither phenol nor cresol. (*e*) A. Leutz notices that the residues from gas, whether it is made from wood, coal, or petroleum, are identical, viz: aromatic hydrocarbons and phenols, naphthaline, anthracene, and phenanthrene, all of which are likewise obtained by passing petroleum through red-hot tubes filled with charcoal. Leutz experimented with Russian petroleum. (*f*) J. Tuttschew passed the vapor of an American naphtha through a red-hot tube filled with pumice and obtained gas and tar. One gram of the naphtha yielded a liter of gas having the following composition: (*g*)

	Per cent.
Acetylene	1.77
Elayl and homologues	20.51
Marsh-gas and hydrogen	77.72

The effects of oxidation upon petroleum and its compounds have been quite widely studied. I succeeded in converting California petroleums into asphalts, which were lustrous black and brittle, soluble in carbon disulphide and fusible at 212° F.; but I have never examined either the asphalt or the gaseous products of the decomposition. (*h*) Walter P. Jenney has very carefully studied the effects of oxidation upon heavy petroleum distillates. He placed these distillates in a metallic still and aspirated a current of air through the oil continuously for from four to six days, maintaining the oil at the same time at a temperature of from 140° to 155° C, and as a result the volume of oil was greatly reduced, not by oxidation into water, but by cracking into lighter oils and gases and the conversion of a portion of the oil into oxidized residues, soluble in chloroform, but not in petroleum naphtha. He says:

> These four substances, formed from one sample of oil, bear a peculiar relation to each other. The resin D, which is in solution in the hot oil, has the composition expressed by the formula $C_{46}H_{46}O_5$. Becoming oxidized, it precipitates as the brown powder $C_{40}H_{40}O_5$, and, settling on the bottom of the still, becomes heated to a higher temperature, changing into the solid asphalt $C_{40}H_{38}O_5$, or by a longer action of air $C_{40}H_{38}O_7$. (*i*)

These interesting and suggestive experiments bear an important relation to the technology of petroleum.

Hell and Mendinger oxidized the acid that they obtained from crude Wallachian petroleum by the action of nitric and chromic acids, and obtained acetic acid and a new acid having the formula $C_9H_{16}O_2$. (*j*) Berthelot has shown that the action of chromic acid on ethylene and its homologues at a temperature of 120° produces aldehyde and its homologues. (*k*) In 1870 E. Willigk treated paraffine at a high temperature with nitric and sulphuric acids, and obtained products that belonged to the series of the fatty acids. (*l*) In 1873, M. Champion subjected paraffine for sixty hours to the action of nitro-sulphuric acid, hyponitric acid vapors were given off, and an oil having been formed with an acid reaction, combining readily with alkalies, of which the formula is $C_{26}H_{26}NO_{10}$, he proposed for it the name paraffinic acid. (*m*) In 1874 M. A. G. Pouchet published a paper in relation to the action of nitric acid upon

a For references see page 60 *et seq.*
b *C. Rendus*, liv, 387.
c *M. Am. Acad.*, N. S., ix, 177; A. J. S. (2), xliii, 250.
d *Jour. Pharm. Chem.* (4), xxii, 241.
e C. N., xxxvi, 140.
f Rus. Chem. Soc., June, 1877.
g J. f. P. C., xciii, 394.
h P. Am. P. S., x, 460; *Geo. Surv. of California:* Geology, Appendix II, 86.
i *Am. Chem.*, v, 359.
j B. S. C. P., 1877–'82, 385; B. D. C. G. B., x, 451.
k J. C. S., xxxvi, 907.
l B. D. C. G. B., 1870, 138.
m *J. de Pharm. et de Chimie*, Aug., 1872.

paraffine and the divers products that result from it. (*a*) He obtained in solution the fatty acids, chiefly caproic, but also butyric, caprylic and capric, and paraffinic acid insoluble. He regards paraffinic acid as having the formula $C_{48}H_{47}O_3,HO$, and paraffine as a definite compound with the formula $C_{48}H_{50}$, and not a mixture of different carbides of hydrogen, a conclusion that does not follow, unless he has shown that paraffines from all sources have the same composition and produce the same paraffinic acid.

In 1868 M. Grotowski, of Halle on the Saale, studying the effects of sunlight on illuminating oil, (*b*) exposed various kinds of oils in glass flasks to the rays of the sun for a period of three months, and found that they invariably absorbed oxygen and converted it into ozone. The air was ozonized even in well-corked vessels, the effect being, however, in some degree dependent upon the color of the glass. The respective results of these experiments were noted after a lapse of three months. American kerosene from petroleum, which had been exposed to the light in white uncovered glass balloons, had become so strongly ozonized that it scarcely burned, and the original bluish-white oil had assumed a vivid yellow color, the specific gravity being found to have increased 0.005; but American kerosene which had been kept in the dark for three months did not show any ozone at all, and burned satisfactorily. The oils were exposed from April to July, 1868. Those oils which had become strongly ozonized had also suffered a distinct change in odor, and the corks were bleached as if attacked by chlorine, while the others had remained unchanged in these particulars. These results are fully confirmed by the experience of the consumers and dealers in these oils, who all avoid obtaining "old oil", as it is called. It appears that redistillation with quicklime and clean iron nails restores the oils to their original state and properties. It is well known that the best illuminating oils, when allowed to stand for a long time in unused glass lamps, become yellow in color, less mobile, and of greatly impaired quality.

Dr. Stevenson Macadam, having investigated the action of petroleum on metals, concludes that it exerts a solvent action upon lead, zinc, tin, copper, magnesium, and sodium. (*c*) Engler refers to these experiments, and maintains that these metals are attacked by petroleum only under the influence of air or oxygen, when acid compounds are formed. Petroleum washed in caustic alkalies and distilled in carbonic acid has no solvent action on metals. (*d*)

Chapter V.—THE ORIGIN OF BITUMENS.

Section 1.—INTRODUCTION.

The origin of bitumens has been a fruitful subject of speculation among scientific men during the last half century. These speculations have been pursued along several quite different lines of investigation, and have been influenced by several different classes of experience. Generally speaking, they fall into three different categories, embracing those who regard bitumen as a distillate produced by natural causes, those who regard bitumen as indigenous to the rocks in which it is found, and those who regard bitumen as a product of chemical action, the latter class being subdivided into those who regard bitumen as a product of chemical change in natural products, of which carbon and hydrogen are constituents, and those who advocate a purely chemical reaction between purely mineral or inorganic materials. I propose to examine these theories in the inverse order in which they have just been stated.

Section 2.—CHEMICAL THEORIES.

The argument for a purely chemical origin of petroleum was first brought to the serious attention of scientific men through the publication of a somewhat noted paper by the distinguished French chemist Berthelot in 1866, whose conclusions are stated as follows:

> If, in accordance with an hypothesis recently announced by M. Daubré, it be admitted that the terrestrial mass contains free alkali metals in its interior, this hypothesis alone, together with experiments that I have lately published, furnishes almost of necessity a method of explaining the formation of carbides of hydrogen. According to my experiments, when carbonic acid, which everywhere infiltrates the terrestrial crust, comes in contact with the alkali metals at a high temperature, acetylides are formed. These same acetylides also result from contact of the earthy carbonates with the alkali metals even below a dull-red heat.
>
> Now the alkaline acetylides thus produced could be subjected to the action of vapor of water; free acetyline would result if the products were removed immediately from the influence of heat and of hydrogen (produced at the same time by the reaction of water upon the free metals) and the other bodies which are found present. But in consequence of the different conditions the acetylene would not exist, as has been proved by my recent experiments.

a *C. Rendus*, lxxix, 320; Dingler, ccxiv, 130; C. N., xxx, 154.
b *N. Jahrbuch f. Pharm.*, xxxvii, 187; Chem. C. Bl., 1872, 588.
c T. P. S. E. (3), viii, 463; J. C. S., xxxiv, 355.
d B. D. C. G. B., 1879, 2186; C. N., xli, 284.

In its place we obtain either the products of its condensation, which approach the bitumens and tars, or the products of the reaction of hydrogen upon those bodies already condensed; that is to say, more hydrogenated carbides. For example, hydrogen reacting upon the acetylene, engenders ethylene and hydride of ethylene. A new reaction of the hydrogen either upon the polymeres of acetylene or upon those of ethylene would engender formenic carbides, the same as those which constitute American petroleum. An almost unlimited diversity in the reaction is here possible, according to the temperature and the bodies present.

We can thus imagine the production by a purely mineral method of all the natural carbides. The intervention of heat, of water, and the alkali metals, together with the tendency of the carbides to unite with each other to form matters more condensed, are sufficient to account for the formation of these curious compounds. Their formation could thus be effected in a continuous manner, because the reactions which give birth to them are continually renewed. This hypothesis is susceptible of further development, but I prefer to dwell within the limits authorized by my experiments without wishing to announce other than geological possibilities. (*a*)

Continuing the same line of experimentation and argument, in 1869 M. Berthelot thus concludes another article:

In the preceding experiments wood, charcoal, and coal are changed into petroleum. * * * If one accepts either origin for petroleum that I have just mentioned, he is led to conceive the possibility of an indefinite formation of these carbides, whether they be relegated to an organic origin, and in consequence to the enormous mass of *débris* buried at an inaccessible depth, or whether they be relegated to a purely mineral origin, and in consequence to the incessant removal of the generative reactions. (*b*)

He further applies this hypothesis to the origin of the carbonaceous matter in the meteorite of Orgueil and other meteorites. (*c*)

In 1871 M. H. Byasson read a paper before the French Academy, which he concludes as follows:

The question of the origin of petroleum has already produced four or five different theories. In a research that certain considerations have led us to undertake, we have, by causing carbonic acid and water to react under very simple conditions, obtained a small quantity of an inflammable liquid nearly indifferent to sulphuric acid, and with an odor analogous to that of the carbides of petroleum. * * * The substances that we cause to react upon each other being widely distributed upon the globe, it will perhaps be possible to formulate a new theory of the formation of petroleum, to correllate it with the elevation of mountains and volcanic eruptions, and to group together several important facts prominent in the history of the earth. (*d*)

M. Byasson causes steam, carbonic acid, and iron at a white heat to react upon each other, and provides the requisite conditions in nature by assuming that sea-water penetrates the terrestrial crust and comes in contact with metallic iron at a white heat and at great depths beneath the surface.

In 1877 Messrs. Friedel and Crafts produced the hydrocarbides and acetones by a complex reaction, in which chloride of aluminum performed the essential part. (*e*)

On the 25th of February, 1877, M. Mendeljeff read a paper on the origin of petroleum before the Chemical Society of Saint Petersburg, which has been very widely noticed. I give below a translation of a *résumé* which appeared in the correspondence of the Chemical Society of Paris, and which is printed in its bulletin:

The appearance of springs of petroleum at the surface of the earth shows the tendency of those mineral oils to traverse by infiltration the different strata of the earth in reaching the surface, a natural consequence of their lower density as compared with water. The place where petroleum originates ought then to be situated beneath the strata where the springs themselves are found. The beds furnishing the mineral oil belong in general to several very different formations of the earth's strata. Thus in the Caucasus the petroliferous zone is formed in the Tertiary; in Pennsylvania, in the Devonian, and even Silurian. The place of the formation of the petroleum ought then to be sought in older strata. The sandstones impregnated with petroleum have never exhibited the carbonized remains of organisms. In general, petroleum and carbon are never found simultaneously; but it is difficult to suppose that petroleum resulted from the decomposition of animal and vegetable organisms, because it would be then impossible to represent the origin of petroleum without a corresponding formation of carbon. On the other side, it is impossible to imagine the existence of great quantities of organisms in the epoch preceding the Silurian and Devonian. These reflections have led the author to the supposition that petroleum is in no place of organic origin. In speaking of the hypothesis of La Place upon the origin of the earth, in applying Dalton's law to the gaseous state in which all the elements constituting the terrestrial globe ought to be found, and taking into consideration their relative densities, M. Mendeljeff recognizes the necessity of admitting a condensation of metals at the center of the earth. Among these it is natural to presume iron would predominate, because it is found in great abundance in the sun in meteorites and basalts. Admitting further the existence of metallic carbides, it is easy to find an explanation not only for the origin of petroleum, but also for the manner of its appearance in the places where the terrestrial strata, at the time of their elevation into mountain chains, ought to be filled with crevices to their center. These crevices have admitted water to the metallic carbides. The action of water upon the metallic carbides at an elevated temperature and under a high pressure has generated metallic oxides and saturated hydrocarbons, which, being transported by aqueous vapor, have reached those strata where they would easily condense and impregnate beds of sandstone, which have the property of imbibing great quantities of mineral oil.

This explanation of the origin of petroleum finds support from the following facts: The predominance at the surface of the earth of elements having a small atomic weight; the appearance of petroleum in directions corresponding to great circles; the relation remarked by several naturalists, particularly by M. Abich, between petroleum and volcanic manifestations.

In order to make this question clear, it is indispensable to study the different transformations of petroleum, its decomposition into marsh-gas and non-saturated hydrocarbons; of determining the chemical nature of mineral oils of different origin; also that of the saline water that ordinarily accompanies petroleum. Researches of this kind, in connection with profound geological studies, can alone render justice to the hypothesis stated above. (*f*)

In 1877 Mr. Clœz succeeded in obtaining hydrocarbons resembling certain constituents of petroleum as a result of the action of dilute sulphuric acid on a carbide of iron and manganese (spiegeleisen). The next year, by

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a *Ann. de Chim. et de Phys.*, Dec., 1866.
b B. S. C. P., xi, 278.
c C. R., lxvii, 849.
d C. R., lxxiii, 609.
e C. R., lxxxv, 74.
f B. S. C. P., 1877, 501.

using a carbide richer in manganese, he succeeded in producing the reaction with boiling water and obtained the oils as before. In concluding his paper on the subject he regards his results as a sufficient basis for an hypothesis by which to account for the origin of petroleum. (*a*)

In 1878 M. Fr. Landolph succeeded in obtaining these oils by an exceedingly complex process, in which he used fluoborates, affirming that "it is the great energy (affinity) of boron for the elements of water that ought to provoke those classes of reaction and permit us to obtain synthetically a great number of carbides of hydrogen with great facility". (*b*)

These chemical theories are supported by great names, and are based on the most complete and elaborate researches; but they require the assumption of operations nowhere witnessed in nature or known to technology.

I quote here a passage which I wrote in 1867, soon after M. Berthelot's original article, above quoted, first appeared:

> The theory of M. Berthelot appears to me to derive less support from observed facts than any which has been proposed. It was doubtless formed with reference to the petroleums of Pennsylvania, which are among the purest mineral hydrocarbons of any found in large quantities. The very small proportion of nitrogen existing in these oils might perhaps be accounted for as an accidental constituent of the limestone, or as being mechanically mingled with the watery vapor. Neither supposition is at all probable, since nitrogen possesses such slight affinities. It adds nothing to its support to admit that the alkali metals do exist in the interior of the earth in the free state. (*c*) The very great difference observed between the varieties of petroleum (*d*) cannot be explained upon any hypothesis that regards them as the results of the same process acting upon like materials; neither should it be expected that a process yielding an almost "unlimited diversity" of products, under slightly varying circumstances, would furnish a uniform result over a very wide area. Samples of Pennsylvania petroleum of the same density, when gathered from widely separated localities, furnish identical (*e*) results upon analysis; so, too, do California petroleums, though gathered from localities 50 miles apart; and yet the two varieties of oil are exceedingly unlike. "It is, moreover, altogether erroneous to attempt to explain the causes of geological facts by the aid of supposed analogies with the complex apparatus of physical cabinets, whose existence in nature could scarcely be conceived by the boldest and most unrestrained imagination." (*f*)

The most conspicuous advocate of the theory that petroleum is a product of chemical reaction, by which marsh-gas is converted into more condensed hydrocarbons, appearing as fluid, viscous, and solid bitumens, is M. Coquand, who has so fully written upon the occurrence of bitumen in Albania and Roumania. He found mud volcanoes associated with the occurrence of petroleum in Sicily, the Apennines, the peninsula of Taman, and the plains of Roumania, and concluded that mud volcanoes produced petroleum and other forms of bitumen by converting marsh-gas into more condensed hydrocarbons. The following passage gives a summary of his opinions:

> If the Carpathians have snown me only mineral oils in the state of naphtha more or less charged with tarry matters, and sometimes, but rarely, glutinous bitumen, that is to say, in the first stage of its existence and transformation, Selenitza ought to show me the same phenomena brought to the extreme limit of exhaustion; that is to say, bitumen reduced to a solid substance, incapable of spontaneous decomposition and of engendering new derivative products. It is rational to conclude that the history of that substance consists of two distinct evolutions, of which the first has for the principal theater of its active life North America and the Carpatho-Caucasian region, and the second the coasts of the Black sea and lower Albania, and as occupying an intermediate position between the two extreme states, which represent birth and death, we will mention glutinous bitumen, an intermediate and unstable substance through which petroleum passes, having lost its primitive fluidity and acquired that consistence which ought always to preserve it, which might be called the period of old age and decrepitude. (*g*)

M. Grabowski, in an article on ozokerite, having advanced similar opinions with reference to marsh-gas, says:

> Very little is known about its formation. It appears to me to be very probable that it has to be considered as a product of the oxidation and condensation of the petroleum hydrocarbons. * * * By this hypothesis the formation of petroleum may be reduced to an oxidation of marsh-gas, and thus the close connection between ozokerite, petroleum, and coal be explained in the most simple manner. (*h*)

No adequate representation of the reaction is given. C. H. Hitchcock has supported similar views. (*i*)

It may be said, in reference to this theory, that, in so far as it expresses the fact that maltha represents an intermediate stage in the transformation of petroleum into asphaltum and recognizes the chemical relation existing between marsh-gas and the petroleum compounds, it is entitled to consideration; but in the chemical processes of nature complex organic compounds pass to simpler forms, of which operation marsh-gas, like asphaltum, is a resultant, and never the crude material upon which decomposing forces act.

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a C. R., lxxxv, 1003, lxxxvi, 1248; J. C. S., xxxiv, 481, 716.

b C. R., lxxxvi, 1267. Professor A. Wurtz has produced some of the constituent hydrocarbons of petroleum by the action of zinc ethyl on iodide of allyl, but with great forbearance he refrains from assuming that these reagents are found in the interior of the earth. C. R., liv, 387.

c This statement is equally true of spiegeleisen, etc.

d See Chapter IV.

e The word *identical* will not apply to the present condition of the Pennsylvania region as it did in 1867, but should be replaced by *similar*.

f P. A. P. S., x, 445. Quotation from Bischof: *Chemical and Physical Geology*; Cav. Soc. ed., i, 243.

g B. S. G. F., xxv, 35.

h Hübner's *Zeitschrift*, 1877, 83; *Am. Chem.*, vii, 123.

i *The Geo. Mag.*, iv, 34.

SECTION III.—THE THEORY THAT BITUMEN IS INDIGENOUS TO THE ROCKS IN WHICH IT IS FOUND.

The opinion that petroleum is indigenous to the rocks in which it occurs has been maintained with great vigor by Dr. T. S. Hunt and Professor J. P. Lesley, these gentlemen basing their views upon their observations in Canada, West Virginia, and Kentucky. Dr. Hunt, having found the fossiliferous limestones impregnated with petroleum, which is particularly abundant in the fossils themselves, therefore concludes:

The facts observed in this locality appear to show that the petroleum, or the substance which has given rise to it, was deposited in the beds in which it is now found at the formation of the rock. We may suppose in these oil-bearing beds an accumulation of organic matters, whose decomposition in the midst of a marine calcareous deposit has resulted in their complete transformation into petroleum, which has found a lodgment in the cavities of the shells and corals immediately near. Its absence from the unfilled cells of corals in the adjacent and interstratified beds forbids the idea of the introduction of the oil into these strata either by distillation or by infiltration. The same observations apply to the petroleum of the Trenton limestone, and if it shall hereafter be shown that the source of petroleum (as distinguished from asphalt) in other regions is to be found in marine fossiliferous limestones a step will have been made toward a knowledge of the chemical conditions necessary to its formation. (*a*)

In a paper published some years later the same gentleman says:

In opposition to the generally received view, which supposes the oil to originate from a slow destructive distillation of the black pyroschists belonging to the middle and upper divisions of the Devonian, I have maintained that it exists, ready formed, in the limestones below. All the oil-wells of Ontario have been sunk along denuded anticlinals, where, with the exception of the thin black band sometimes met with at the base of the Hamilton formation, these so-called bituminous shales are entirely wanting. The Hamilton formation, moreover, is more oleiferous, except in the case of the rare limestone beds, which are occasionally interstratified. Reservoirs of petroleum are met with both in the overlying quaternary gravels and in the fissures and cavities of the Hamilton shales, but in some cases the borings are carried entirely through these strata into the corniferous limestone before getting oil. A well was sunk at Oil Springs to a depth of 456 feet from the surface and 70 feet into the solid limestone beneath the Hamilton shales before meeting oil. (*b*)

He says further, in support of this opinion:

In this (the Trenton) we meet for the first time with petroleum, though in much less abundance than in the higher rocks. In the township of Packenham, the large orthoceratites of the Trenton limestone sometimes hold several ounces of petroleum in their chambers, and it has been met with under similar conditions in Lancaster. It has also been observed to exude from the fossil corals of the Birdseye limestone at Riviére à la Rose (Montmorency). The limestones of this group, which are generally more or less bituminous to the smell, are peculiarly so in some parts of the county of Montmorency, and not only give off a strong odor when struck, but when burned for lime evolve an abundant bituminous vapor on the first application of heat. The lithological representative of the Trenton group next appears in the corniferous formation, composed, like the former, of pure limestones, with chert beds, silicified fossils, and petroleum. * * * It is in the Lower Devonian limestone, or corniferous formation, that the greatest amount of petroleum occurs, although Mr. Hall observed that the dolomites of the Niagara formation in Monroe county, New York, frequently contain mineral pitch, which is sometimes so abundant as to flow from the rock when this is heated in a lime-kiln. Concretionary nodules holding petroleum have also been observed in the Marcellus and Genesee slates, while the higher Devonian sandstones in New York and Pennsylvania are often impregnated with petroleum, and from these and from still higher strata issue the oil-springs of those regions. It is probable, however, that the source of the oil in these superior strata is to be found in the corniferous limestone, from which the petroleum of western Canada is undoubtedly derived. * * * In the township of Rainham, on lake Erie, the shells of *Pentamerus aratus* are sometimes found to have an inner cavity, lined with crystals of calcite and filled with petroleum. Coralline beds impregnated with petroleum are found at Wainfleet and in Walpole, in the latter instance immediately beneath a layer of chert; but I have more particularly examined them in the township of Bertie, which is on the Niagara river opposite Buffalo. Here in a quarry are seen massive beds, slightly inclined, composed of a solid, crystalline, encrinal limestone, which appears not only destitute of petroleum, but, from the water by which it is impregnated, to be impermeable to it. In some of the beds are large corals of the genus *Heliophyllum*, the pores of which are open but contain no oil. Two beds, however, one of 3 and one of 8 inches, which are interstratified with these, are in a great part made up of species of *Heliophyllum* and *Favosites*, the cells of which are full of petroleum. This is seen in freshly-broken masses to be absent from the solid limestone, which forms the matrix of the corals, and resembles in texture the associated beds. As the fractured surfaces of the oil-bearing beds become dry, the oil spreads over them, and thus gives rise to the appearance of a continuous band of dark oil-stained rock, limited above and below by the lighter limestone, from which, however, it is separated by no planes of bedding. The layer of 3 inches was seen to be twice interrupted in an exposure of a few feet, thus presenting lenticular beds of the oil-bearing rock. Beside the occasional specimens of *Heliophyllum* without oil disseminated in the massive limestone, a thin and continuous bed of *Favosites* is met with, which is white, porous, and free from oil, although beds above and below are filled with it. It was in the weathered outcrop of one of these that was obtained the specimen in the cells of which was found the infusible and insoluble product of the oxidation of petroleum. When the oil-bearing beds are exposed in working the rock the oil flows out and collects on the water of the quarry. The facts observed in this locality appear to show that the petroleum, or the substance that has given rise to it, was deposited in the bed in which it is now found at the formation of the rock.

In the easternmost part of North America, and at the extremity of the peninsula of Gaspé, petroleum is again met with issuing from sandstones which belong to the base of the Devonian series. Beds of thickened petroleum, like those of Enniskillen, are here met with. Near to cape Gaspé there is a remarkable dike of amygdaloidal trap, 10 or 12 yards in breadth, the cavities of which are often lined with chalcedony or with crystals of calcite and quartz. Many of these cells are filled with petroleum, which in some cases has assumed the hardness of pitch. (*c*)

Petroleum occurs saturating a stratum 35 to 40 feet thick about midway in the Niagara formation at Chicago, Illinois, the rock being so filled with petroleum that blocks of it which have been used in buildings are discolored by the exudations, which, mingled with dust, form a tarry coating upon the exposed surfaces. Though thus discolored, when freed from the bitumen, this rock is a nearly white, crystalline dolomite. An illustration of the effect of this exudation was to be noticed in one of the largest churches in Chicago before the great fire.

a A. J. S. (2), xxxv, 168. *b Ibid.*, (2), xlvi, 361. *c* A. J. S. (2), xxxv, 157.

Dr. Hunt estimated the amount of oil held in the Niagara limestone of Chicago, and found it to be 4.25 per cent., an amount rather beneath the average. He continues:

A layer of this oleiferous dolomite, 1 mile (5,280 feet) square and 1 foot thick, will contain 1,184,832 cubic feet of petroleum, equal to 8,850,069 gallons of 231 cubic inches, and to 221,247 barrels of 40 gallons each. Taking the minimum thickness of 35 feet assigned by Mr. Worthen to the oil-bearing rock at Chicago, we have in each square mile of it 7,743,745 barrels, or, in round numbers, 7,750,000 barrels of petroleum. * * * With such sources existing ready formed in the earth's crust, it seems to me, to say the least, unphilosophical to search elsewhere for the origin of petroleum, and to suppose it to be derived by some unexplained process from rocks which are destitute of the substance. (*a*)

In reply to a letter of inquiry, Professor James M. Safford thus writes regarding the occurrence of petroleum in the neighborhood of Nashville, Tennessee:

In the limestone rocks of Nashville, representing those of the Silurian basin of middle Tennessee, and of course Silurian (lower), geodes or geode cavities in certain horizons are quite common. They are mostly calcite geodes, or cavities lined with crystals of calcite. Sometimes there is nothing but the calcite crystals within; then we have a lining of calcite crystals with dolomite, gypsum, anhydrite, often cleavable, and occasionally fluorite within. I have seen all of these minerals in one. Imperfect quartz geodes lined with quartz crystals occasionally occur. Barite and celestite and baryto-celestite occur together, and sometimes fluorite occurs with these. In a certain horizon there are many geode cavities lined with calcite crystals and containing within beautiful crystals of celestite, white and beautifully blue. Cavities occur containing celestite which are not lined with calcite crystals, and it is not uncommon to meet with geode cavities in our limestones lined with calcite crystals and containing more or less petroleum. I have seen as much as half a pint or even more in them.

There appears to be little room to doubt that the petroleum in these geodes is indigenous to the Nashville limestone.

The Clinton limestones of Ohio, lying immediately above the Cincinnati group and over the whole northern border of the Cincinnati anticlinal, contains petroleum in small quantities, but nowhere sufficient in amount to be of economic value. (*b*)

In the description of the method of "the existence of the petroleum in the eastern coal-field of Kentucky" Professor J. P. Lesley says:

At Old Oil Springs, on the south fork of Paint creek, a black reservoir of tar-like oil here occupies the center of a sloping bog, and is kept always full from a spring at its upper limit, near the top of the slope and foot of the cliffs, about 20 feet above the level of the stream. Fig. 3 shows the conformation of the ground, *a* the spring, *b* the reservoir, *c* the bed of Paint creek, *d* conglomerate No. XII. (*c*)

A mile farther down the stream, but on the opposite or right bank, and apparently 35 or 40 feet above the water, on a steep slope close under the projecting cliffs, is a similar spring, which has not produced any extensive bog for want of a level receptacle, but has yielded "large quantities" of oil in past years, and from which petroleum continues to run slowly all of the time. Fig. 4 shows the contour of the ground and the overhanging cliffs at two places near the spring. Three miles farther down the stream, and within a mile or less of its junction with the north or Open fork at Lyon's well, the oil is to be seen coming from the edge of the coal and ore-shales, just under the cliffs, which here tower to an amazing height. Fig. 5 represents in a formal manner this section and a pile of conglomerate crag called the Crow's Nest, between 100 and 200 feet high. There are here, immediately underneath the lowest plate of conglomerate (20 feet thick), 5 feet of shales, then 2 feet of yellow sandstone, then 1½ to 3 inches of ball ore, then black and blue slates to the creek level. A mile or two up the creek there are in these black slates two distinct beds of coal, 6 feet apart, the upper 10 inches, the lower 24 inches thick; and oil flows from them continually in small quantities. At Davis, where the road crosses Paint creek, just below the mouth of Little Glade run, the conglomerate being here 230 feet thick and the streams flowing from the bottom of it between straight vertical walls, the black petroleum is perpetually welling out, not only from under the conglomerate, but from crevices in the bare faces of the rocks, accompanied, as elsewhere, by yellow peroxide of iron.

It is evident from the description given above—and the same description will answer for a large number of similar springs in the numerous gorges through which the Licking waters find their way westward into the Blue Grass country of middle Kentucky—that the petroleum of the oil-springs of Paint creek (*d*) has had its home in the great conglomerate at the base of the coal measures; still has, we may say, for it is still issuing in apparently undiminished quantities from the same. A conglomerate age or horizon of petroleum exists. This is the main point to be stated, and must be kept in view, apart from all other ages or horizons of oil, whether later or earlier in order of geological time. The rock itself is full of the remains of coal plants, from the decomposition of which the oil seems to have been made. I noticed in the great rock pavement at Lyon's well, over which the creek water flows, many sections of tree branches and stems mashed flat, each section being, say, 6 inches long by one-eighth of an inch wide in the middle, and when a jack-knife was thrust down into the slit, so as to clear it of mud, the black tarry oil would immediately exude and spread itself over the water. A pointed hammer spalling off flakes of the rock on each side showed not only that the slit itself was full of thick oil, but that the whole rock was soaked with it, except along certain belts (an inch or less wide and very irregular), which for some unexplained reason remained free from oil. Some of the great blocks of rock that have fallen from the cliff too recently to be as yet decomposed are literally full of the marks of the broken macerated driftwood of that period. For hundreds of square miles this vast stratum of ancient sea sand is a thick packed herbarium of coal-measure plants. If the loose sands of the bank of Paint creek, derived, as they are, from this sand-rock, can at the present day receive and retain vast quantities of petroleum in spite of the perpetual washings to which they are subjected, we can easily conceive of the wide, flat, sandy shores of the coal islands of the ancient archipelago of the coal era becoming completely charged with the decomposed and decomposable reliquiæ of both the plants of the land and the animals of the sea. (*e*)

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It is as yet beyond our ability to distinguish the several original sources of the petroleum obtained at different depths from any one well. The specific gravities of the oil, decreasing with the increase of depth, is a fact which shows conclusively that a chronic evaporation or distillation of the whole mass of oil in the crust of the earth (within reasonable reach of the surface) has always been, and is still, going on, converting the animal and plant remains into light oils, the light oils into heavy oils, the heavy oils into asphalt or albertite, the process being accompanied at every stage with the liberation of gas. Therefore the quantities of lubricating oil coming out from the

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a A. J. S. (3), i, 420.

b Professor Edward Orton in a communication to S. F. Peckham.

c P. A. P. S., x, 39.

d Professor Lesley appears to regard the name "Paint creek", as suggested by the iridescent film of petroleum floating on the water.

e P. A. P. S., x, 39.

conglomerate along the valleys of Paint creek prove the existence of immense quantities back from the cliff in the rock itself under all the highlands. And for the same reason the heavy oils obtained first from Lyon's and Donnell's and Warner's wells, followed by lighter oils from a greater depth, prove the existence of yet uncalculated quantities of still lighter oils at still greater depths, and of a world of gas-pressure which ought to make its presence known whenever there have been rents in the crusts, down-throws, fallings-in, or serious slopings of the stratification; in a word, any sort of natural vent. (*a*)

The paper from which these extracts are taken was read before the American Philosophical Society, April 7, 1865. It expresses the opinion of which Professor Lesley has been one of the strongest advocates, that the petroleum of the Appalachian system is indigenous to the rocks in which it is found. It is to be inferred, however, that his views as related to the origin of the petroleum found in northwestern Pennsylvania have become somewhat modified, although in precisely what manner is not clear. In the introduction to Report III of the *Second Geological Survey of Pennsylvania*, p. xv, Professor Lesley says:

The origin of petroleum is still an unsolved problem. That it is in some way connected with the vastly abundant accumulations of Paleozoic sea-weeds, the marks of which are so infinitely numerous in the rocks, and with the infinitude of coralloid sea animals, the skeletons of which make up a large part of the limestone formations which lie several thousand feet beneath the Venango oil-sand group scarcely admits of dispute, but the exact process of its manufacture, of its transfer, and of its storage in the gravel beds is utterly unknown. That it ascended rather than descended into them seems indicated by the fact that the lowest sand holds oil, when those above do not, and that upper sands hold oil when they extend beyond or overhang the lower.

If I understand Professor Lesley, these later statements, as well as that quoted regarding the chronic distillation that has always been, and still is, going on, express his opinion respecting the changes that convert the original petroleum content of the rocks into the different varieties of petroleum now met with, rather than the origin of the petroleum itself.

Professor T. Rupert Jones examined the asphaltic sand or rock of Trinidad, and found that when it is boiled several times in spirits of turpentine "it loses its bitumen and resolves itself into loose orbitoides and nummulinæ, with a few other foraminifera, and (when cleaned by acid) a small proportion of green-black sand and a very few rounded grains of quartz". (*b*)

In a paper on the "Geology of a part of Venezuela and Trinidad" Mr. G. P. Wall describes the occurrence of bitumen as follows:

The asphalt of Trinidad is almost invariably disseminated in the upper group of the "Newer Parian". (*c*) When *in situ* it is confined to particular strata, which were originally shales containing a certain proportion of vegetable *débris*. The organic matter has undergone a special mineralization, producing bituminous in place of ordinary anthraciferous substances. This operation is not attributable to heat, nor to the nature of distillation, but is due to chemical reaction at the ordinary temperature and under the normal conditions of the climate. The proofs that this is the true mode of generation of the asphalt repose not only on the partial manner in which it is distributed in the strata, but also on numerous specimens of the vegetable matter in process of transformation and with the organic structure more or less obliterated. After the removal by solution of the bituminous material, under the microscope a remarkable alteration and corrosion of the vegetable cells becomes apparent, which is not presented in any other form of the mineralization of wood. A peculiarity attending the formation of the asphalt results from the assumption of a plastic condition, to which property its frequent delivery at the surface is partly referable; where the latter is hollow or basin-shaped, the bitumen accumulates, forming deposits such as the well known Pitch lake. Sometimes the emission is in the form of a dense oily liquid, from which the volatile elements gradually evaporate, leaving a solid residue. Mineral pitch is also extensively diffused in the province of Maturin, on the main (the other districts of the llanos were not sufficiently examined to determine its existence, which, however, is generally affirmed), and in still larger quantities near the gulf of Maracaibo, on the northern shores of New Granada and in the valley of the Magdalena, where it probably is a product of the same Tertiary formation. (*d*)

In England petroleum has been observed in a peat bog, and the lower layers of the peat were compacted into a sort of bituminized mass, which has been described by E. W. Binney as follows:

The only remarkable feature connected with the upper bed of peat at Down Holland Moss is the western portion of it being covered up with a bed of sand, and being probably sometimes subject to an infiltration of sea-water. * * * These circumstances, added to the fact of petroleum being found most plentifully at the edge of the sand, lead to the conclusion that it is produced by the decomposition of the upper bed of peat under the sand.

The chemical process by which such singular effects have been produced is a subject more fitted for the consideration of the chemist than the geologist, but the author supposes that petroleum is the result of slow combustion in the peat, and has been produced by a process partly analogous to that which takes place in the distillation of wood in closed vessels, when, owing to a total absence of oxygen, the combination of hydrogen and carbon in the form of hydrocarbons is effected. (*e*)

Petroleum has also been observed dripping from shales overlying a highly bituminous coal; (*f*) also in limestone containing remains of crustacea. (*g*)

Concerning the origin of the petroleum of Shropshire, Arthur Aiken says:

The thirty-first and thirty-second strata are coarse-grained sandstone entirely penetrated by petroleum; are, both together, 15½ feet thick, and have a bed of sandy slate-clay about 4 feet thick interposed between them. These strata are interesting as furnishing the supply of petroleum that issues from the tar-spring at Coalport. By certain geologists this reservoir of petroleum has been supposed to be sublimed from beds of coal that lie below, an hypothesis not easily reconciled to present appearances, especially as it omits to explain how the

a P. A. P. S., x, 53.
b Q. J. G. S., xxii, 592.
c A South American Tertiary group.
d Q. J. G. S., xvi, 467.
e *Proc. Manchester Lit. and Phil. Soc.*, iii, 136.
f T. G. S. L. (2), v, 438.
g *Ibid.* (1), ii, 199.

petroleum in the upper of these beds could have passed through the interposed bed of clay so entirely as to leave no trace behind. It is also worthy of remark that the nearest coal is only 6 inches thick, and is separated from the above beds by a mass 96 feet in thickness, consisting of sandstone and clay strata, without any mixture of petroleum. (*a*)

The observations of Wall in Trinidad appear to establish beyond a doubt that the bitumen of that locality has been and is being produced from a peculiar decomposition of woody fiber. Bright and Priestwich both regard the petroleum of England as indigenous in the limestones and shales, and the testimony of Binney is conclusive as to its production from the decomposition of peat on Down Holland Moss.

Professor A. Winchell says:

It seems to have become established from recent (1866) researches that the petroleum of the Northwest not only accumulates in several different formations, but also originates from materials stored up in rocks of different geological ages from the Utica slate to the coal conglomerate, and perhaps the coal measures. (*b*)

Professor J. D. Whitney has suggested that the infusoria, the remains of which are so abundant in certain sedimentary rocks, are the original source of the petroleum occurring in them, and says:

In conclusion, it may be remarked that the marine infusorial rocks of the Pacific coast, and especially of California, are of great extent and importance. They occur in the coast ranges from Clear lake to Los Angeles. They are of no little economical as well as scientific interest, since, as I conceive, the existence of bituminous materials in this state, in all their forms, from the most liquid to the most dense, is due to the presence of infusoria. (*c*)

Section 4.—THE THEORY THAT BITUMEN IS A DISTILLATE.

Humboldt, in 1804, observed a petroleum spring issuing from metamorphic rocks in the bay of Cumana, and remarked:

When it is recollected that farther eastward, near Cariaco, the hot and submarine waters are sufficiently abundant to change the temperature of the gulf at its surface, we cannot doubt that the petroleum is the effect of distillation at an immense depth, issuing from those primitive rocks beneath which lie the forces of all volcanic commotion. (*d*)

The researches of Reichenbach led him to suggest, in 1834, that "when we remember that coal is so filled with the remains of plants that its origin has been attributed entirely to the destroyed vegetables of an early period, it must appear probable that petroleum was formed from such plants as afford these oils, and, in one word, that our mineral oil is nothing but turpentine oil of the pines of former ages; not only the wood, but also the needle-like leaves, may have contributed to this process, which is not a combustion, but is, I believe, simply the result of the action of subterranean heat." (*e*)

French writers generally have expressed their conviction that bitumens have resulted from the action of heat on strata containing organic matter.

In 1835 M. Rozet read a paper before the Société Géologique de France, in which he discussed the occurrence of asphaltic limestone at Pyrmont. He represents it as a mass of limestone not stratified, but crossed with fissures in all directions, and contains 9 to 10 per cent. of bitumen and pure carbonate of lime. The limestone is accompanied by a molass or a sort of breccia, consisting of gravel of quartz and schistose rocks cemented with asphalt. The molass contains from 15 to 18 per cent. of asphalt, but the bitumen extracted from the limestone and molass is identical. He continues:

The bituminous matter is found equally in the calcareous rock and the molass that covers it. It is evident that the action that introduced it into the two rocks is posterior to the deposition of the latter. The manner in which it disistributed in great masses, which throw their ramifications in all directions, joined in such a manner that the superior portions contain generally less bitumen than the remainder of the mass, indicate that the bitumen has been sublimed from the depths of the globe. * * * The nature of the bituminous rocks (molass, cretaceous limestone, and calcareous schist) admit perfectly of this sort of action. The molass and the limestone are so porous that they easily absorb water and the calcareous schist sticks to the tongue. Thus these rocks could have been easily penetrated by the bituminous vapors, which probably penetrated all three of them at the same time.

The epoch of the introduction of the bitumen into the preceding rocks being necessarily posterior to the deposition of the molass, it may be presumed that it corresponds to that of the basaltic eruptions which many facts prove to have been often accompanied with bituminous material. * * *

It may be objected that such basaltic rock does not appear in all the extent of the Jura. To that I reply that they are found in the neighborhood, in Burgundy and in the Vosges; and further, that in the changes in the surface of the soil, whether occasioned by fractures or by the disengagement of vapors, the plutonic rocks do not necessarily appear at the surface. Perhaps in the deep valleys of the Jura the basalts are at a very slight depth. * * * In the Val de Travers, near Neufchatel, similar phenomena are observed. (*f*)

In 1846 Mr. S. W. Pratt described the occurrence of bitumen at Bastenee, a small village in the south of France, 15 miles north of Orthez. The surrounding country is formed of small conical hills 200 or 300 feet high, separated by a coarse sandy limestone belonging to the cretaceous system. The upper part consists of variously colored sands and clays from 50 to 60 feet thick, the whole covered by gravel and sand, which in all directions

a T. G. S. L. (1), i, 195.

b A. J. S. (2), xli, 176.

c *Bul. Acad. Sci. San Francisco*, iii, 324. Dr. J. S. Newberry has lately erroneously attributed this theory to S. F. Peckham, *Ann. N Y. Acad. Sci.*, ii, No. 9.

d *Humboldt's Travels*, III, 114, Bohn's ed.

e *Schweigger Seidel's Jahrbuch*, ix, 133; *Ph. Jour.*, xvi, 376.

f B. S. G. F. (1), vii, 138.

extends for many miles. These sands and clays are usually horizontal; but are occasionally disturbed and highly inclined. This is occasioned by the protrusion of igneous matter, which is there found in connection with them. The bitumen is worked in three localities near each other, and occurs in beds from 5 to 15 feet thick, which vary much in character, the upper part consisting of looser and coarser sand, with a less proportion of the bitumen, while the lower part is more compact, containing finer sand, and being chiefly composed of bitumen. The sands and clays contain no fossils except occasional pieces of lignite and bitumen, and are generally free from extraneous matters, except in two localities, where numerous shells are found which may be referred to the Miocene period. In one of these localities, where the bitumen bed is from 10 to 12 feet thick, the shells are disposed in numerous layers a few inches apart, those of the same kind generally forming distinct layers, though sometimes, where the layer is thicker, many species are found together; and where the mass has been cut through vertically the appearance is very striking, bright, white lines appearing on a black bed of bitumen. The shells are neither broken nor disturbed, but are perfectly preserved, nor are the valves separated; but, owing to the loss of animal matter, on being exposed to the air they fall into powder. Perfect casts may be readily procured, as they easily separate from the sandy mass. The bitumen has evidently been forced into them when in a soft or liquid state, as the smallest cavities are filled, and this must have taken place after their deposition in the sands in which the animals lived. The date of this formation, as indicated by numerous species, may be referred to the Miocene era; and as the eruption of bitumen is evidently connected with the appearance of the ophite, an igneous rock which has produced such great changes in the Pyrenees, a limit may thus be obtained for these changes. (*a*)

In a notice upon the occurrence of asphalt in the environs of Alais, published in 1854, M. Parran makes the following statements:

Whatever be the origin of these substances, whether they be due to interior emanations from fissures of dislocation or to circumstances exterior and atmospheric, it is evident that there was during the Tertiary period an asphaltic epoch (*époque asphaltique*) in relation to which it is convenient to recall the numerous eruptions of trachytes and basalts which characterize that period and have probably acted by distillation upon the masses of combustibles hidden in the bosom of the earth.

He further remarks that asphalt occurs between Mons and Auzon, and continues:

The lacustrine formation, of which we have studied the bituminiferous part, is deposited in a vast depression of the secondary formation (*terrains*), represented here by the lower cretaceous and chloritic formations (*néocomienne et chloriteés*).

M. Parran concludes as follows:

Emanating by distillation from beds of combustible material inclosed in the inferior Cretaceous (*néocomienne*) formation or perhaps in the Carboniferous, if, as is probable, they extend to that place, the bitumen is raised in the midst of the fresh-water limestones (*calcaires d'eau douce*); there it is fixed by imbibition. Hot springs and sulphur springs abound in the vicinity. (*b*)

In 1868 M. Ch. Knar published an article on "The theory of the formation of asphalt in the Val de Travers, Switzerland". His conclusions are:

1. Asphalt (limestone impregnated with bitumen) is due to the decomposition in a deep sea of beds of mollusks, the decomposition taking place under a strong pressure and at a high temperature.

2. The free bitumen is formed also by the decomposition of certain mollusks or crustaceans in a sea of little depth, at a high temperature, but under an insufficient pressure to make this bitumen impregnate the oyster shells (*pour former ce bitume à imprégner les coquilles d'huitre*).

3. Petroleum is due to the decomposition under water of mollusks, a decomposition which has taken place at a temperature too low to transform it into bitumen (asphalt), but under a pressure more or less considerable.

4. The beds of white limestone formed also by the accumulation of fossil oysters, and which contain neither asphalt nor petroleum, have been formed under such conditions that the products of the decomposition of animal organic matter have been evaporated.

5. Finally, combustibles only, or pyroschists (*bitumés fixes*), have been formed by the decomposition of plants, while all the preceding are of animal origin. (*c*)

In 1872 M. Thoré published a paper on the "Presence of petroleum in the water of Saint Boés (Basses-Pyrénées)", in which he says "petroleum floats on the water of the springs, and the rocks are saturated with it", and continues:

The comparison of observations seems to indicate in the department of the Basses-Pyrénées between the lower and middle Cretaceous formations a considerable impregnation of petroleum, due probably to igneous action or an eruption of ophite. The more this origin is examined the more one is convinced, because the greater part of the deposits of petroleum which prove valuable to the countries in which they are found are evidently related to the rocks of igneous origin, which may be considered as being the principal cause of its formation, or, at least, of the appearance of mineral oil. (*d*)

In 1837 M. Dufrenoy showed that the change from colored to white marble in the Pyrenees was due to the expulsion of bitumen by heat. (*e*) It is also maintained that jet is a distillate. (*f*)

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a Q. J. G. S., ii, 80.

b *Ann. des Mines* (5), iv, 334. $(C_aSO_4)_2 + C_3 = (C_aCO_3)_2 + CO_2 + S_2$. The hydrogen of the bitumen also becomes oxidized and H_2S is formed.

c *Mon. Sci.*, 1868, 381.

d *L'Année Sci. et Ind.*, 1872, 251.

e B. S. G. F. (1), ix, 238.

f Simpson. San Franciso Min. and Sci. Press, 1874, 246.

One of the most noted papers on petroleum that has appeared in the United States was published by Dr. J S. Newberry in 1859. In this paper he says:

The precise process by which petroleum is evolved from the carbonaceous matter contained in the rocks which furnish it is not yet fully known, because we cannot in ordinary circumstances inspect it. We may fairly infer, however, that it is a distillation, though generally performed at a low temperature.

We know that vegetable matter—and the same may be said of much animal tissue when the conservative influence of life has ceased to act—if exposed to the action of moist air, is completely disorganized by a process which we call decay, which is in fact combustion or oxidation. This change takes place slowly, and without evolution of light and heat, the usual accompaniments of combustion, in a degree appreciable by our senses.

When, however, carbonaceous organic tissue is buried in moist earth or submerged in water oxidation does not at once ensue, or at least takes place to a limited extent, measured by the amount of oxygen present. In these circumstances bituminization takes place. This process consists mainly in the union of hydrogen, from the tissue itself or its surroundings, with a portion of the carbon, to form carbureted-hydrogen, which perhaps escapes, and the hydrocarbons constituting the bitumen, which usually remains as a black, pitch-like mass, investing the fixed carbon. By this process peat, lignite, and coal are formed, which are solids, and doubtless some liquid and gaseous hydrocarbons which escape. Now, when we heat these solid bitumens artificially at a sufficiently high temperature, if in contact with oxygen, combustion ensues, and water and carbonic acid are formed from them. At a lower temperature they are converted into gaseous hydrocarbons; still lower to oils. (*a*)

In an article published by Professor E. B. Andrews in 1861 he calls attention to the fact that the town of Newark, Ohio, has been for several years lighted by the uncondensed gas from the coal-oil manufactories, and infers that in the spontaneous distillation of bituminous substances a large amount of gas must be generated along with the oil. He refers to the theory which had been recently brought forward by Dr. Newberry, and says:

The chief objection to it is the fact that the coal, cannel and bituminous, in our oil regions gives no evidence of having lost any of its full and normal quantity of bitumen or hydrocarbons. For example, at Petroleum, Ritchie county, Virginia, where strata have been brought up by an uplift from several hundred feet below, seams of cannel and bituminous coal appear, which, if judged by the standard of Nova Scotia or English coals, have lost none of their bituminous properties. * * *

The other theory, that the oil was produced at the time of the original bituminization of the vegetable or animal matter, has many difficulties in its way. If the oil were formed with the bitumen of the coal, we should expect that wherever there is bituminous coal there would be corresponding quantities of oil. This is not so, in fact; for there is no oil, except in fissures in the rocks overlying the bituminous strata. * * * Again, upon this theory, it will be difficult to explain the large quantities of inflammable gas always accompanying the oil. If it is generated exclusively from the oil, then we should expect to find the quantity of the oil least where the gas-springs have for ages been most active, but at such places the oil, instead of being wasted, is most abundant. (*b*)

The distinguished French geologist, Daubrée, had published the previous year his *Studies upon Metamorphism*, in which he had discussed the relation of bituminous substances to metamorphism as follows:

Bitumens and other carbides of hydrogen, according as their state is solid, liquid, or gaseous, whether impregnating beds, flowing as petroleum, escaping from the soil, as in salses, mud volcanoes, burning springs, etc , are in general only the vent-holes (èvents) of deposits of bitumens. The different deposits of bitumen present as general or at least remarkably frequent characteristics:

1. Association with saline formations.
2. Being situated in the neighborhood of deposits of combustible minerals, or strata charged with vegetable *débris*.
3. Being associated with igneous accidents, ancient or modern; that is to say, with volcanoes or irruptive rocks, or with dislocated strata.
4. Frequently accompanying thermal springs, often sulphurous, and deposits of sulphur. (*c*)

Several of my experiments account for these relations. In submitting fragments of wood to the action of superheated steam I have changed it into lignite, coal, or anthracite, according to the temperature, and I have also obtained liquid and volatile products resembling natural bitumens and possessing the characteristic odor of the petroleum of Pechelbronn. It is thus that the presence of bitumen in certain concretionary metalliferous veins is accounted for; as, *e. g.*, Derbyshire, Camsdorf, and Raibl, in Carinthia.

Finally, bitumens are probably derived from vegetable substances; as it appears not to be a simple product of dry distillation, but to have been formed with the concurrent action of water, and perhaps under pressure, graphite being only the most exhausted (*épuisé*) product of these substances. These divers compounds of carbon are incident, then, to certain transformations which take place in the interior of the rocks, apparently under the influence of an elevated temperature. The activity and even the violence, at times capable of producing slight earthquakes, with which carbureted hydrogen has sometimes been associated in the Tauride, on the borders of the Caspian sea, and in the environs of Carthagena, in South America, prove that the action that has sometimes disengaged bitumen continues to the present time. (*d*)

Section 5.—AN ATTEMPT TO INCLUDE OBSERVED FACTS IN A PROVISIONAL HYPOTHESIS.

The studies which I have made upon petroleum, extending now over a period of more than twenty years, and especially those which I have made in preparing this report, lead me to the conclusion that as yet very little is known regarding its chemical geology. As no one has studied the chemical properties of different varieties of petroleum in relation to their geological occurrence in any effective manner, it would be extremely rash for any one to dogmatize with reference to the origin of bitumens. I am, however, led to state the conclusions that a careful survey of our available knowledge of the subject has enabled me to reach. I am convinced that all bitumens have, in their present condition, originally been derived from animal or vegetable remains, but that the manner of their derivation has not been uniform. I should therefore exclude both classes of chemical theories; the first as

a Rock Oils of Ohio; *Ohio Ag. Rep.*, 1859.

b A. J. S. (2), xxxii, 85.

c I have omitted the numerous illustrations.

d *Études sur le Métamorphisme*, p. 73. M. Daubrée adds in a note: "Graphite and bitumen are associated in Java in proximity to volcanic formations and a Tertiary lignite, from which jets of carbureted hydrogen escape."

impossible, the second as unnecessary. There remains the hypothesis that bitumen is indigenous in the rocks in which it is found and that which regards all bitumens as distillates, but whichever of these hypotheses be accepted, the modifying fact remains that there are four kinds of bitumen:

1. Those bitumens that form asphaltum and do not contain paraffine.
2. Those bitumens that do not form asphaltum and contain paraffine.
3. Those bitumens that form asphaltum and contain paraffine.
4. Solid bitumens that were originally solid when cold or at ordinary temperatures.

The first class includes the bitumens of California and Texas, doubtless indigenous in the shales from which they issue. It is also probable that some of the bitumens of Asia belong to this class.

I have described the conditions under which bitumens occur on the Pacific coast of southern California in great detail in the reports that I have made to the geological survey of that state, (*a*) the forms found there being almost infinite in gradation, from fluid petroleum to solid asphaltum; but I have been unable to obtain any information from the parties who are operating in Santa Clara county other than that contained in newspaper reports, which are too unreliable to be used in this connection. In Ventura county the petroleum is primarily held in strata of shale, from which it issues as petroleum or maltha, according as the shales have been brought into contact with the atmosphere. The asphaltum is produced by further exposure after the bitumen has reached the surface. These shales are interstratified with sandstones of enormous thickness, but I nowhere observed the petroleum saturating them, although it sometimes escaped from crevices in the sandstone; nor was the bitumen held in crevices of large size nor under a high pressure of gas, as the disturbed and broken condition of the strata, folded at very high angles, precluded such a possibility.

The relation of the asphaltum to the more fluid materials became a question of great importance to those engaged in prospecting for petroleum in that region in 1865 and later, and having made the solution of this problem a constant study for months, I finally came to the conclusion expressed above. My opinions were based on the following facts: a quantity of petroleum from the Cañada Laga spring remained in an open tank for fifteen months fully exposed to the elements, and increased 0.035 in specific gravity. Maltha has been obtained in wells so dense as to lead to their abandonment. Three attempts were made by the Philadelphia and California Petroleum Company to drill a well on the San Francisco ranch, and the greatest depth reached was 117 feet; but at that depth the maltha was so dense that it could not be pumped out, nor could it be drawn out with grappling-hooks, and was so tenacious as to clasp the tools so firmly as to prevent further operations. These wells were located near an asphalt bed on a gently sloping hillside, where the strata were very much broken and easily penetrated by rain-water. The Pico spring, yielding petroleum issuing from shales, overlaid with unbroken bands of thick sandstone, was only a short distance beyond in the same range of hills, and still further were several other localities, all yielding more or less fluid maltha from natural springs, wells, and tunnels. The density of the bitumen, however, was in every case in direct proportion to the ease with which rain-water could percolate the strata from which it issued. On the plains northwest of Los Angeles an artesian boring that penetrated sandstones interstratified with shale yielded maltha at a depth of 460 feet.

Perhaps that portion of the sulphur mountain lying between the Hayward Petroleum Company's tunnels in Wheeler's cañon and the Big Spring plateau on the Ojai ranch furnishes the most striking illustration of the occurrence of bitumens in this region. A section of the strata at this point is given in Fig. 6. From this section it will be perceived that there is a synclinal fold in the shale forming the mountain, and that the strata dip into the mountain on both sides. The belt of rock yielding petroleum on the south side, in which the tunnels are driven, is fully protected by from 700 to 800 feet of shale, while the mountain side is nearly perpendicular. On the opposite side, however, the belt comes to the surface, presenting the upturned edges over a nearly horizontal area. These tunnels yielded the lightest petroleum at that time obtained in southern California, while the maltha in the Big Spring that issued from the detritus covering the shale was so dense in December, 1865, that it was gathered and rolled into balls, like dough, and removed in that condition. (*b*)

The topography and stratigraphy of the coast ranges of Santa Barbara, Ventura, and Los Angeles counties are very complex. The Santa Barbara islands are volcanic, and lava-flows are described as having formed cascades over cliffs of sedimentary rocks as they descended into the sea. On the mainland no lava appears to have reached the surface, although between Las Posas and Simi, along the stage-road leading from San Buenaventura to Los Angeles, on an eroded plateau surrounded by low mountains, fragments of scoriæ are scattered over the ground. The coast ranges here appear to have been produced by parallel folds, each successively higher, by which enormously thick beds of sandstone, interstratified with shale, were thrust up at an angle of about 70°, producing parallel anticlinals. These anticlinals were subsequently eroded in such a manner as in many instances to produce valleys and plateaus, where the sandstones are broken through to the softer shales beneath. This is the case with the western extremity of the fold which, commencing at point Concepcion, extends eastward to Mount San Bernardino. West of the Sespé the sandstone crest has been completely removed and the shales cut away, until, at the Rincon, east of Santa Barbara, the erosion reaches the sea-level, and beyond, to the westward, the upturned edges of the shale form the bed of the ocean. The narrow plain on which Santa Barbara stands, lying between the

a *Report Geological Survey of California:* Geology, II. Appendix, pp. 48-90.

b S. F. Peckham, Am. C., iv, 6.

Santa Iñez mountains and the sea, consists of Pliocene and Quaternary sands and gravels resting upon the eroded shales. East of the Rincon and mount Hoar the table-lands lying in the trough of the anticlinal gradually ascend until at the Sespé the sandstone caps the high mountain to the eastward, said to be the highest in that region. This range extends eastward, occasionally broken by transverse cañons, until, near the headwaters of the Santa Clara river, at the Soledad pass, it becomes merged in the San Rafael range, beyond the San Fernando pass.

Between point Concepcion and point Rincon, where the stratum of sand occurs saturated with maltha, (*a*) the latter has risen and floated on the sea and attracted the notice of travelers ever since that coast was known to Europeans. At point Rincon, where the anticlinal recedes from the coast, maltha rises and saturates the Quaternary sands. As the ascending plateau passes farther inland, we find in the line of hills east of mount Hoar and in the Santa Iñez mountains a line of outcrop of the bituminous strata on the east and west sides of the basin. East of the San Buenaventura river the local synclinal fold in the shale forming the sulphur mountain gives four lines of bituminous outcrop, shown on the section, Fig. 6*b*. In the cañons east of the Sespé, wherever the bituminous strata have been reached by erosion, tar-springs and asphalt beds are the result. The deeply eroded narrow valleys which cover the country east of Santa Barbara and south of the coast range present in a distance of a few miles the greatest lithological variations, and expose the bituminous strata under the greatest possible diversity of conditions. For this reason we meet here every possible form of bitumen in every possible degree of admixture, with pure sand, soil, detritus, and animal and vegetable remains.

The exceedingly unstable character of these petroleums, considered in connection with the amount of nitrogen that they contain and the vast accumulation of animal remains in the strata from which they issue, together with the fact that the fresh oils soon become filled with the larvæ of insects to such an extent that pools of petroleum become pools of maggots, all lend support to the theory that the oils are of animal origin. (*b*)

The second class of petroleums includes those of New York, Pennsylvania, Ohio, and West Virginia. These oils are undoubtedly distillates, and of vegetable origin. The proof of this statement seems overwhelming. Pennsylvania petroleum was examined in 1865 by Warren and Storer (*c*) in this country, and in 1863 by Pelouze and Cahours in France, (*d*) who found the lighter portion to consist of a certain series of hydrocarbons, identical with those obtained in the destructive distillation of coal, bituminous shales, and wood when the operation was conducted at low temperatures. Messrs. Warren and Storer also discovered that the same series of hydrocarbons could be obtained by distilling a lime soap prepared from fish-oil. (*e*) The experience of technology has shown that if coals or pyroschists are distilled at the lowest possible temperature, particularly in the presence of steam, a black tarry distillate is obtained, along with a considerable quantity of marsh-gas and very volatile liquids, that cannot be condensed except at low temperatures. If these distillates are redistilled, the second distillate may be divided into several different materials, beginning with marsh-gas and ending with very dense oils, heavily charged with paraffine. It is impossible to conduct this primary or secondary distillation without producing marsh-gas, but the amount and the density of the fluid produced will depend on the temperature at which the distillation is carried on and the rapidity of the process. The use of superheated steam is found to increase the quantity of the distillate, and to prevent overheating and the formation of other hydrocarbons than those belonging to the paraffine series.

The section compiled by Mr. Carll shows the Devonian shales above the corniferous limestone and below the Bradford third oil-sand to be 1,600 feet in thickness. This shale outcrops along lake Erie, between Buffalo, New York, and Cleveland, Ohio. It is for the most part the surface rock in the neighborhood of Erie, Pennsylvania, and southward to Union City, and no one can examine it without noticing the immense quantity of fucoidal remains that it contains. Professor N. S. Shaler discusses in much detail the extent and character of the Devonian black shale of Kentucky, and estimates it to cover 18,000 square miles at an average depth of 100 feet, and to yield on distillation 15 per cent. of fluid distillate. It is not necessary to follow him in his calculations of the enormous bulk of this distillate as represented in barrels; the important point in this connection is that it is a very persistent formation, being revealed by borings over a very wide area, and doubtless extends beyond the boundaries of Kentucky, eastward beneath the coal measures which contain the petroleum. (*f*)

If, however, the Devonian black shales are inadequate, both on account of extent and position, as a source of supply, we may descend still lower in the geological series to the Nashville limestone and other Silurian rocks that underlie that region. Professor Safford, in a recent letter, writes:

The Lower Silurian limestone in the basin of middle Tennessee is about 1,000 feet thick. I have divided it in my *Geological Report* into the Lebanon limestone (or division) and the Nashville, each about 500 feet, the Nashville being the upper division. Including the Upper Silurian limestones, the whole thickness of the limestones, in which are found occasionally little pockets or geodes and cavities of petroleum, is not far from 1,200 feet.

	Feet.
Upper Silurian	200
Lower Silurian (Trenton):	
Nashville limestones	500
Lebanon limestones	500

The most of the petroleum has been found in the upper part (the Nashville) of the Lower Silurian, as, for example, the larger cavities near or on the upper Cumberland river, in the neighborhood of the Kentucky line, both within Kentucky and Tennessee.

a See page 21.
b S. F. Peckham, P. A. P. S., x, 452.
c *Mem. Am. Acad.* N. Si., ix, 176; A. J. S., (2), xli, 139.
d *Ann. C. et P.* (4), 1, 5.
e *Mem. A. A. N. S.*, ix, 177.
f *Rep. Geo. Survey, Kentucky*, N. S., iii, 109

These limestones underlie the whole petroleum region of southeastern Kentucky and middle Tennessee.

The objection urged by Professor Andrews, that the coals in the measures of West Virginia and Ohio among which these oils occur have lost nothing of their volatile content, is without force here. Professor Shaler (*Report of the Geological Survey of Kentucky*, new series, iii, 171) says:

The condition of the beds that lie below the black shale in the Cincinnati group or in the Niagara section show that there has been no great invasion of heat since the beds were deposited. Clays, which change greatly under a heat of 1,000° F., are apparently exactly as they were left by the sea, and beds retain their marine salts just as when they were deposited. Any great access of temperature in this deposit of the Ohio shale would have been attended by an almost equal rise of temperature in the coal-beds which lie within a few hundred feet above; but these coal-beds are free from any evidences of distillation or other consequences of heat. We have already seen reasons for supposing an erosion of some 3,000 or 4,000 feet of strata from this section; if we could reimpose this section we should probably bring up the temperature of these rocks by the rise in the isogeothermals, or lines of equal internal heat, about 60°. * * * We are not able to suppose that the accumulation of strata would have elevated the temperature above the boiling point of water.

The hypothesis which may be found to account for the formation of this coal-oil must take into consideration the impossibility of its generation at another point and its removal to this set of beds and the impossibility of supposing that it has been in any way the result of high temperatures.

The range of temperature between "the boiling point of water" and "1,000° F.", which is here allowed, is ample for all purposes of explanation.

Mendeljeff objects that "the sandstones impregnated with petroleum have never exhibited the carbonized remains of organisms. In general, petroleum and carbon are never found simultaneously". These three objections—first, that the supply of organic matter is inadequate; second, that there are no evidences of the action of heat upon the rocks holding the oil; third, that there are no residues of fixed carbon observed in the rocks holding the oil—are those which have appeared to satisfy those who do not accept the hypothesis that regards petroleum as a distillate. I think the first has been already answered. The second and third I shall now examine.

It is not the effects of heat, as represented by volcanic action, that have produced petroleum, although in one notable instance paraffine and other constituents of petroleum have been found in the lava of Etna. (*a*) A comparison of the analyses of the gaseous emanations of volcanoes with those of gas and petroleum springs shows that the former consist mainly of carbonic acid and nitrogen, while the latter consist mainly of marsh-gas. Bitumens are not the product of the high temperatures and violent action of volcanoes, but of the slow and gentle changes at low temperature due to metamorphic action upon strata buried at immense depths.

The extent of the Paleozoic formations of the Mississippi valley and the general conformation of the bottom of the ancient seas has been fully described by Professor James Hall, who says: (*b*)

In all the Lower Silurian limestones we trace the outcrop to the west and northwest from the base of the Appalachians, in New York or in Canada, to the Mississippi river, and thence still in the same northwesterly direction. * * * Instead of finding the lower Helderberg (Upper Silurian) strata in lines parallel with those of the preceding rocks, the relative direction of the main accumulation and the principal line of exposures is diagonally across the others. * * * The line of outcrop and of accumulation has been from northeast to southwest, and they occur in great force far to the northeast in Gaspé, on the gulf of Saint Lawrence. * * * The greatest accumulation of material in the period of the Hamilton, Portage, and Chemung groups (Lower and Middle Devonian) lies in the direction of the Appalachian chain. * * * In Gaspé there are 7,000 feet of strata, * * * while in western New York the whole together would scarce exceed 3,000 feet. We have therefore the clearest evidence that the strata thin out in a westerly direction. * * * In considering the distribution of the masses of the formations which we have here described we find that the greatest accumulations have been along the direction of the Appalachian chain. The material thus transported would be distributed precisely as in an ocean traversed by a current like our present Gulf Stream, and in the gradual motion of the waters during that period to the west and southwest the finer material would be spread out in gradually diminished quantities, till finally the deposit from that source must cease altogether. * * * I have long since shown that * * * the portion of the Appalachians known as the Green Mountain range is composed of altered sediments of Silurian age. * * * The evidences in regard to the White mountains, to a great extent, are of newer age than those of the Green mountains, or Devonian and Carboniferous. * * * The statements of Sir William Logan in regard to the great accumulation of strata in the peninsula of Gaspé, together with the observations of Professor Rogers in the Appalachians of Pennsylvania, lead to the inevitable conclusion that the sediments of this age must everywhere contribute largely to the matter forming the metamorphic portion of the Appalachian chain, as well as to the non-metamorphic zone immediately on the west of it.

Reference to Map III shows the manner in which the outlined areas that have yielded petroleum correspond to the trend of these deposits of sediment as described by Professor Hall.

It is not necessary here to discuss the nature or origin of metamorphic action. It is sufficient for our purpose to know that from the Upper Silurian to the close of the Carboniferous periods the currents of the primeval ocean were transporting sediments from northeast to southwest, sorting them into gravel, sand, and clay, forming gravel bars and great sand-beds beneath the riffles and clay banks in still water, burying vast accumulations of sea weeds and sea animals far beneath the surface. The alteration, due to the combined action of heat, steam, and pressure, that involved the formations of the Appalachian system from point Gaspé, in Canada, to Lookout mountain, in Tennessee, involving the carboniferous and earlier strata, distorting and folding them, and converting the coal into anthracite and the clays into crystalline schists along their eastern border, could not have ceased to act westward along an arbitrary line, but must have gradually died out farther and farther from the surface.

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a Silvestri, *Gaz. Chim. Ital.*, vii, 1; *Chem. News*, xxxv, 156; B. D., C. G., 1877, 293.

b *Nat. Hist. N. Y.*, Paleontology, iii, 45–60.

The great beds of shale and limestone containing fucoids, animal remains, and even indigenous petroleum, must have been invaded by this heat action to a greater or a less degree, and that "chronic evaporation" of Professor Lesley must have been the inevitable consequence.

Too little is known about petroleum at this time to enable any one to explain all the phenomena attending the occurrence of petroleum on any hypothesis; but it seems to me that the different varieties of petroleum, from Franklin dark oil, near the surface, to Bradford and Clarendon amber oil, far beneath the surface, are the products of fractional distillation, and one of the strongest proofs of this hypothesis is found in the large content of paraffine in the Bradford oil under the enormous pressure to which it is subjected. So, too, the great pools of oil in southern Kentucky are without doubt distilled from the geode cavities beneath and concentrated in superficial fissures of the rocks near the surface. The oil of the American well is very different in many respects from Pennsylvania oil; and that from the Phelps well, on Bear creek, Wayne county, Kentucky, has an odor identical with that of the petroleum of southern California, in that respect totally unlike the petroleum of West Virginia, and evidently an oil of animal origin that has not been subjected to destructive distillation.

If this hypothesis, which embraces all the facts that have thus far come within my knowledge, really represents the operations of nature, then we must seek the evidences of heat action at a depth far below the unaltered rocks in which the petroleum is now stored. We ought to expect to find the coal in its normal condition. We should not expect to find the carbonized remains of organisms in the rocks containing petroleum. As the metamorphic action took place subsequent to the carboniferous era, we should expect to find the porous sandstones of that formation in certain localities saturated with petroleum. We should expect a careful observer like General A. J. Warner to write concerning them:

Now, while these several sand rocks when they come to the surface contain calamites, stigmaria, and other fossil plants of the lower coal measures, they contain nothing from which petroleum could possibly have been derived. (*a*)

Moreover, we should expect to find these coal-measure sandstones and conglomerates on the western border of the heated area, where the thinning out of the deposits brought down the coal measures nearer the Devonian shales and Silurian limestones, first saturated with petroleum, and then, through ages of repose, gradually cut down by erosion into the cañons of Johnson county, Kentucky, and exhibiting all of the phenomena described by Professor Lesley.

The inadequacy of the scattered remains of plants in the coal-measure sandstones as a source of the petroleum that saturates them is shown by the following calculation:

Should the Mississippi send down one tree a minute for a century, with an average length of 40 feet and a foot in diameter, and these be laid together side by side at the bottom of the sea in a single stratum, they would only cover a space of 200 acres. Were it possible, which it is not, to compress and crystallize these lignites into one stratum 6 feet thick, they might then constitute a coal-bed covering 20 acres. All the forests of the Mississippi valley could not furnish to the sea from their river spoils during a hundred thousand years one of the anthracite coal-beds of Schuylkill county. (*b*)

M. Coquand gives the following *résumé* of the geological formations represented in Roumania:

The Tertiary formation in connection with the clays of the steppes constitutes a continuous and concordant system, in which may be distinguished at the base the nummulite beds representing the great Paris limestone.

1. The Superior Eocene, composed at its base of rock-salt, gypsum, saliferous slates, bituminous schists, and marls with menilites; and above of the "Flysch formation" properly speaking, consisting of alternations of micaiferous sandstones (*macigno*), of limestones (*albérèse*), and of argillaceous schists (*galestri*), this superior part being characterized by *Chondrites Targioni, intricatus, furcatus,* and by *alveolinus*, the ensemble corresponding to the fucoidal Flysch of Switzerland, the Apennines, Algeria, Sicily, the gypsums of Montmartre, and the saline and sulphurous gypsum of Sicily; also the rock-salt of the high plateau of Algeria.

2. The Miocene stage, which is the first level of petroleum in the Carpathians. The inferior part comprises at its base sandstones and saline slates, with *Cyrena convexa* and sandstones corresponding to those of Fontainebleau, the superior part of sandstones, slates, and limestones corresponding to the molass of Carry and Syracuse; also to the gypsum and rock-salt of Volterra, in Tuscany, and the province of Saragossa, to *Marinen Tegel und Sand* (*néogoène* of M. Haidinger); to the *terrain tertiaire miocène marin* of M. Abich; to the *terrain tertiaire inférieur* of M. de Verneuil. The superior part comprises slates and the *grés à congéries* with lignites, amber, and asphalt, and is characterized by *Paludina, Achatiformis, Congeria subcarinata*, Cardium, Souriéffé, etc., corresponding to the *Congerientschisten* of MM. Haidinger and Hauer (*partie supérieure de leur terrain tertiaire néogène*), to the *terrain tertiaire supérieur* of M. de Verneuil, and to the Pliocene of M. Abich.

3. Pliocene stage, which is the second level of petroleum in the Carpathians. It comprises conglomerates and pudding-stones at its base, and above black slates, producing the steppe formation of Moldavia and Wallachia. It corresponds to the superior marine sub-Apennine formation, to the steppes of the Crimea and the Caucasus, to the desert of Sahara, and the marine deposits of Kertsch with *Ostrea lamellosa, Brocchi; Chama gryphina, Lani; Calyptrea sinensis,* and *Linni.*

4. The recent formations comprising the earthy deposits in the environs of Busćo and the recent alluvium of the Danube.

It is noted further, according to M. Coquand, "that the petroleum of Wallachia is in the inferior Tertiary, with mud volcanoes and rock-salt; that the "*Flysch à Fucoids*" is the horizon in Moldavia corresponding to the formation in which it occurs in the Crimea, Transylvania, Galicia, Volterra of Tuscany, the Apennines, Sicily, and Algeria, being everywhere rich in fucoids", who further remarks "that it is only in the slates that it preserves its liquid state, and when it had been brought in contact with permeable rocks, such as sandstones, those rocks imbibed the mineral oil and were changed into asphalt. He accounts for this by assuming that in the porous strata the oil loses by evaporation its volatile principles. He further remarks that the petroleum is not in the rock-salt, but in the slates contiguous to it, rich in fucoids and the remains of marine animals. (*c*)

a A. J. S. (3), ii, 215. *b* J. P. Lesley: *A Manual of Coal and its Topography*, page 49. *c* B. S. G. F. (2), xxiv, 505.

In Galicia the petroleum is found saturating coarse and fine sandstones in zones or horizons, the lighter oils being found deepest.

This sandstone is abundantly permeated with limestone; yet in all fissures and on almost all surfaces the products of dry distillation are plainly recognizable, as also earth-wax and tough black maltha, and particularly asphalt. These products of distillation in many places extend even up to the surface, particularly in the northwestern part of the oil-bearing formations. The cavities of asphaltum were known in ancient times, and the thick fluid earth-oil which oozed out upon the surface was sometimes used as a lubricant for the axles of wheels. (*a*)

The largest yield of petroleum has not been found in the neighborhood of asphalt beds, but farther east, where gas-springs called attention to the probability of reaching petroleum below the surface. It was remarked that the harder the sandstone the greater the pressure of gas and the deeper the source of the oil.

Fig. 7 gives a section from Boryslaw, in east Galicia, to Schodinca. It exhibits a synclinal of schists, standing, where exposed, nearly perpendicular and flanked with sandstones. The wells are sunk in the schists. It resembles a section of the sulphur mountain in California. (See Fig. 6, page 68.)

The conclusions reached by geologists regarding the occurrence of petroleum in Galicia show that the central core of the Carpathians consists of metamorphic rocks, on the flanks of which lie the members of the cretaceous and tertiary formations, consisting of limestones, sandstones, and shales, the latter being, for the most part, rich in organic matter, both vegetable and animal, such as fossil fucoids and fish. In east Galicia and Bukowina heavy beds of black bituminous shales are particularly noticeable. (*b*) These formations lie in folds, the petroleum occurring under the arches of anticlinals rather than in the troughs of the synclinals.

The facts to be obtained regarding the occurrence of the petroleum of Asia are very few. It appears to be generally conceded that the formation from which the petroleum in the neighborhood of the Caucasus arises is Tertiary, but so far as I can ascertain it issues rather from erratic beds of sand in superficial clays than from any well-defined formation. Lartet appears to regard the bitumen of the Dead sea as of volcanic origin. (*c*) The petroleum of Java lies in the Tertiary beneath alluvium, which flanks the volcanic core of the island. (*d*)

Granting that the petroleum of the Niagara limestone at Chicago is indigenous, the invasion of that limestone by steam under high pressure would cause the petroleum to accumulate in any rock lying above sufficiently porous or fissured to receive it. The mingling of oils that contain paraffine and oils that produce asphaltum, and the occurrence of paraffine in large masses in porous strata filled with the remains of fucoids and marine animals that flank the core of crystalline metamorphic schists in Roumania and Galicia, offers the strongest support to this hypothesis. The fact that the eruptive rocks of lake Superior and the metamorphic rocks farther east prevail to such an extent that that vast inland sea has been supposed to be the crater of an extinct volcanic lake lends the strongest support to an hypothesis that regards the vast accumulations of petroleum in western Canada as due to the invasion of strata on the borders of this heat-center, in which the petroleum is indigenous, by a sufficiently elevated temperature to cause its distillation.

It appears to me that mud volcanoes and hot springs are properly regarded as the phenomena attending the gradual subsidence of metamorphic action in the crust of a cooling earth, and that petroleum or maltha is but the accident of such phenomena, when strata containing organic matter are still invaded at a great depth by a temperature sufficient to effect the distillation of their organic content. Gas-springs may also own the same origin, or the gas may escape from deep-seated reservoirs, the product of a distillation long since completed.

The fourth class of solid bitumens occur in great variety. The universal distribution of bituminous material in rocks was noticed in 1823 by the Hon. Geo. Knox, in a paper read before the Royal Society of Great Britain. (*e*) The occurrence of disseminated bitumen in metamorphic rocks at Nullaberg, in west Sweden, supposed to be Laurentian, has been described; (*f*) also in the Lower Silurian of south Scotland, (*g*) in Trap, near New Haven, Connecticut, (*h*) and in northern New Jersey, (*i*) all of which are manifestly the result of the action of heat upon the organic matter in stratified rocks. The occurrence of bituminous limestones in France and the valley of the Rhone, and the almost unanimous opinion of the French geologists that they are the result of igneous or metamorphic action, has already been mentioned.

There remain the phenomena attending the occurrence of large veins of solid bitumen in Cuba, West Virginia, and New Brunswick, for which no adequate explanation has been proposed that does not regard them as a product of distillation from deep-seated strata, which has been projected into a fissure formed by the sudden rupture of the earth's crust. Dr. R. C. Taylor examined the vein which occurs in metamorphic rocks near Havana, and gives a section (Fig. 8) of the vein as it is exposed in the working of the mine. He says:

It was evidently originally an irregular open fissure, terminating upwards in a wedge-like form, having various branches, all of which have been subsequently filled with carbonaceous matter, as if injected from below, and that not by slow degrees, but suddenly and at once. (*j*)

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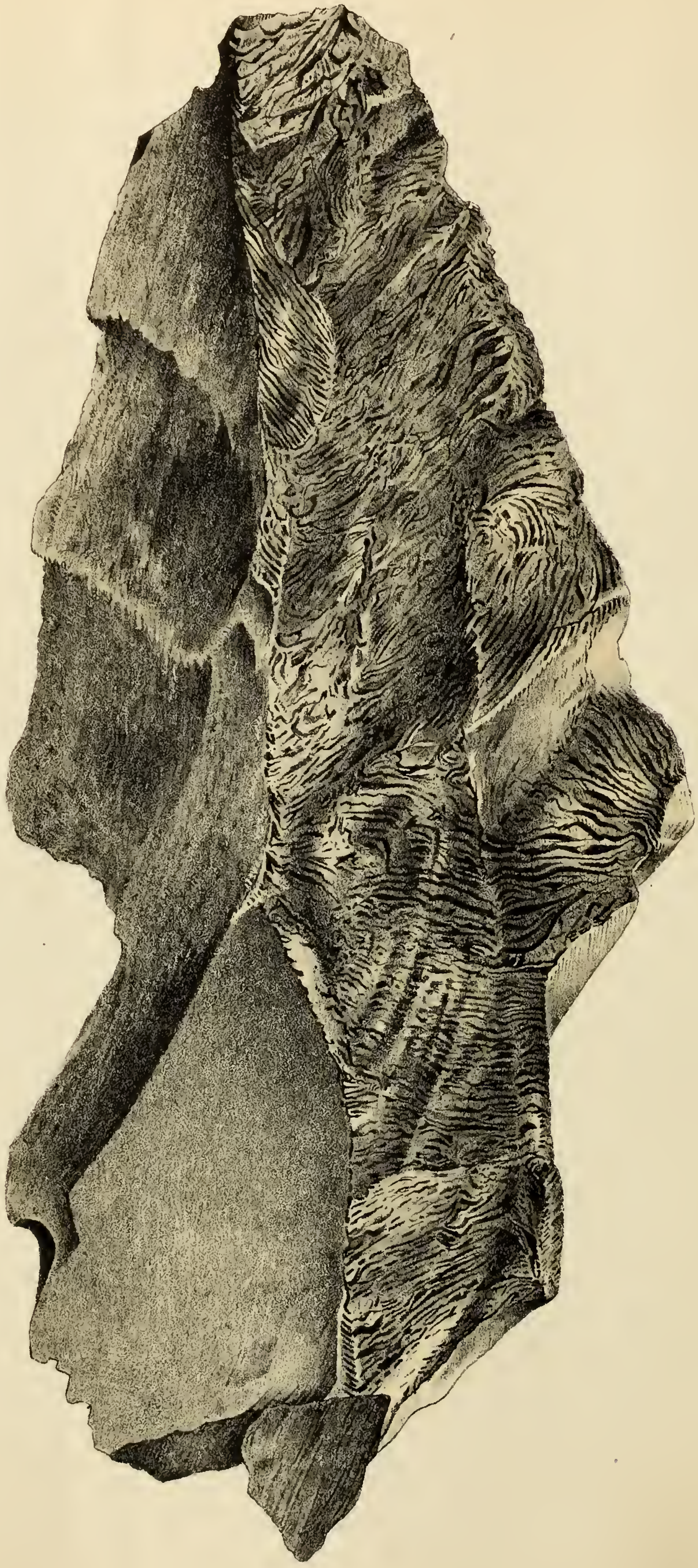
a J. K. K. G. R., xviii, 311.
b Bruno Walter, J. K. K. G. R., xxx, 115.
c B. S. G. F., xxiv, 12.
d Bleekrode, C. N., v, 188.
e *Phil. Trans.*, 1823.
f L. J. Inglestrom: *The Geo. Mag.*, iv, 160.
g *Quar. Jour. Geo. Soc.*, xi, 468.
h A. J. S. (1), xxxvi, 114; (3), xvi, 112.
i A. J. S. (3), xvi, 130.
j *Phil. Mag.*, x, 161.

Plate I.



DRAWING OF A PIECE OF THE HURONIAN SHALE ENCLOSING THE ALBERTITE VEIN IN NEW BRUNSWICK, SHOWING THE MANNER IN WHICH THE ALBERTITE CLEAVES FROM THE ENCLOSING ROCK.

In 1869 I made the origin of albertite and allied substances the subject of a paper, (*a*) in which I discussed the views held by others regarding it and compared them with the observations made in New Brunswick and West Virginia by Jackson, Wetherell, Lesley, Wurtz, and others, with my own observation of a vein on the coast of California. This latter vein is exposed on the coast west of Santa Barbara, and stands vertical, cutting the Pliocene and recent sands. With this vein are associated lenticular masses, extending horizontally, from which a sort of talus projects vertically into the sands beneath. The eruptive origin of these deposits is beyond question.

Similar deposits are described by M. Coquand as occurring in Albania, as follows:

The bitumen at Sélenitza does not lie in regular beds, but in masses, in the midst of the sandstones and conglomerates that preserve a sort of parallelism, each mass consisting essentially of a central portion of considerable thickness, which gradually thins out in all directions to zero. In no case does the bitumen penetrate the roof above the mass, but was evidently injected from below. Fig. 2 (*b*) shows a deposit that has furnished an enormous quantity of bitumen. These deposits occur as if during the sedimentation of the rocks at the bottom of the tertiary area the bitumen in a viscous state had filled the depressions in which it has accumulated, remaining pure or being incorporated with the slaty materials with which it is contaminated. A section of the mass corresponds in many cases to a flask filled with solidified water. The aligned basins appear to have been filled successively from the overflow of one into the other. It is evident that the masses, in spite of their irregularity, are parallel with the stratification. Generally the bitumen consists of compact, very homogeneous matters, and next to this variety the bituminous breccia should be mentioned. This consists of beds of gray slate of varying thickness, inclosing angular fragments of bitumen, separated from each other, but which are easily obtained by soaking in water the slate which serves to cement them. This breccia is represented by Fig. 9, often overlying a bed of asphalt, into which it passes by insensible gradations, and seems to form the upper portion of a liquid bath, into which the slate plunged and afterward regained the surface before its entire solidification. Exactly as in a blast-furnace, the slag becomes mingled with the metal in the last products of the tapping, producing a species of magma. More rarely the bitumen rolls itself upon itself (Fig. 10), thus producing spheres analogous to those which invest viscous matters when rolled in water or dust. The structure of them is concentric, resembling pea-stone, but is destitute of any nucleus so far as observed. These envelopes might result from progressive desiccation, the result of which leaves the bitumen divided into thin pellicles, like certain basalts, in which, on cooling, spheres of variable volume are produced composed of concentric coats. The globules are for the most part isolated in the midst of the slate, and are about one-third of an inch in diameter. Another curious form is shown in Fig. 11. It consists of an infinite number of threads crossing each other in all directions, producing a sort of stockwork. Fig. 12 shows a form which differs from the preceding in that the threads instead of being scattered in a capricious plexus are vertical and parallel. The contraction of the sandstone having opened these vertical and parallel vents, the bitumen following filled them, but from above downward. Sometimes the bitumen, as indicated by Fig. 13, is molded in cup-like depressions, which are terminated by a capillary tube. At other times ellipsoidal masses are introduced, some of which are as large as a cannon-ball. They are aligned in positions parallel to the plane of the beds in which they repose. Masses of sandstone are sometimes met inclosed within the bitumen. Such are sometimes observed in beds of coal.

It is to be observed that the threads that sometimes connect the masses of bitumen spring from the side and not from the top of them—a fact that is explained if we assume the ascending mass overflowed horizontally in this particular locality.

A great many bivalves, especially *Cardium*, were observed filled with bitumen. He also discovered a very large Planorbis and other species with the interior filled with bitumen. After showing that the material could not have entered the rocks in a fluid state, he says: "It is then in the condition of glutinous bitumen that the maltha primarily entered the formation at Sélenitza. There is no evidence of the phenomena of salses, nor solfataras, nor volcanoes, which distinctively characterize the occurrence of petroleum properly so called."

M. Coquand states that there exists at present at one point in the ancient excavations a sort of crater that emits smoke and a great heat, but he assumes that the fire was lighted by the hand of man, which, as in burning collieries, slowly pursue their work of destruction. The clays from which the volatile products are expelled become a sort of brick, sonorous and red, and the sandstones are converted into porcelainites and quartzite, and break at the least shock into a thousand fragments. Fig. 14 represents a section of the rocks in which the bituminous strata occur.

M. Coquand mentions in connection with the bituminous strata solfataras and mud volcanoes, both active and extinct, with which was associated more or less fluid maltha, which is at first very liquid, but soon becomes sirupy, and is finally added to the accumulations of the bituminous cone. The volcanic phenomena assume three forms: First, when inflammable gas escapes through the soil; second, when they escape with water and petroleum, forming craters of bitumen; third, volcanoes emitting hot water (*volcan ardent*). (*c*)

From the foregoing it will appear that solid bitumen occurs in great abundance, filling variously-formed cavities in the Pliocene strata of Albania, and that maltha accompanies the water of springs from deep-seated strata, often in close proximity to active or extinct volcanic action of the mild forms observed as solfataras, mud volcanoes, or salses.

The great similarity in the occurrence of intruded tertiary bitumens in Albania and California is very remarkable.

No hint is given by Dr. Taylor respecting the age of the rocks inclosing the bitumen vein in Cuba, as at the time he wrote (1837) all metamorphic rocks were called primary. There is little doubt, however, that the vein in

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a A. J. S. (2), xlviii, 362.

b See page 32.

c B. S. Q. F., (1), xxv, 35. The precise volcanic phenomenon designated by M. Coquand as *volcan ardent* is not clear. In one case it appears to be an ordinary volcano emitting lava, and in the present case a hot-water volcano; but he afterward remarks that the Tertiary formations in the valley of the Vojutza do not contain the least trace of volcanic action, nor is there a volcanic or thermal spring in the whole country. I presume he refers in this latter sentence to outflows of scoriæ and lava, and does not include in the phrase *volcanic action* the mud volcanoes and solfataras, which he describes at some length.

New Brunswick and in West Virginia originated at nearly the same time and subsequent to the Carboniferous era, and it is certain that subsequent to that era a great convulsion caused an upheaval that in collapse produced the White Oak anticlinal. Very near the southern end of this anticlinal the vein of grahamite occurs, cutting the horizontal sandstones of the coal measures vertically, but those who mined the vein declare that the material must have welled up from beneath into the fissure the instant it was formed, numerous fragments of the wall-rock being found imbedded in the asphaltum only 12 or 15 feet below the cavities from which they fell, with all their edges and angles sharp and exactly fitting each other. Curious curved lines, resembling those produced when a stone is dropped into mortar, are formed on these horses, suggesting the probability that they fell into a plastic mass that rolled upon them, producing lines of unequal pressure and adhesion that remain after the asphaltum has cleaved from them or the inclosing walls. Moreover, these walls of porous sandstone have not absorbed the bitumen to the thickness of a piece of paper. The significance of these facts was more forcibly impressed upon my mind when I found among a set of specimens from the albertite vein of New Brunswick a piece of the inclosing shale, marked with the mineral in forms almost identical with those observed on the sandstone in West Virginia. Plates I and II are very carefully drawn from specimens from the two localities.

It should be borne in mind that while this subject is one of speculation, pure and simple, it is one that has its valuable consideration outside the domain of scientific inquiry or curiosity, as affecting the sources and duration of supplies of petroleum, its profitable development, and commercial permanence.

If petroleum is the product of a purely chemical process, we should not expect to find Paleozoic petroleums of a character corresponding with the simple animal and vegetable organisms that flourished at that period, and tertiary petroleums containing nitrogen, unstable and corresponding with the decomposition products of more highly organized beings, but we should expect to find a general uniformity in the character of the substance, wherever found, all over the earth.

A mass of polypi undergoing decomposition upon a beach would doubtless saturate the sand with about the same kind of decomposition products as an equal bulk of algæ; but when a mass of animal matter, consisting not only of the muscular tissue, but of all the non-nitrogenous substances entering into animal organisms, was thus subjected to decomposition, submerged in water, the product could not fail to be a nitro-hydrocarbon, which upon exposure to atmospheric oxygen would undergo a second decomposition into a greater or less number of the following-named products: carbon, hydrocarbons, ammonia or free nitrogen, carbonic acid, and water. The petroleums of southern California, issuing primarily from Miocene shales, are of precisely this unstable character. (*a*)

The advocates of the chemical theory affirm that they provide for a process the conditions of which are perpetually renewed. It is thus continuous and at present active. On the contrary, if petroleum is the product of metamorphism, its generation is coexistent only with that of metamorphic action; an action which we have no reason to believe has been prevalent on a large scale during the recent period. If we accept this hypothesis, the generation of petroleum is then practically ended.

M. A. Rivière has published a paper on the origin of combustible minerals. (*b*) His opinions are based on his observations of the effect on soil and organic matter in the soil of the leakage of illuminating gas from the pipes in which it is conducted. The effects which he attributes to marsh-gas are, however, due to the condensation of the tarry matter that is dissolved in the escaping gas, the coal-tar products produced at a high temperature not being constituents of petroleum to any great extent. The experiments of Professor Sadtler indicate the presence of minute quantities of benzole in the Bradford oil of Pennsylvania, (*c*) but it was not found by Warren and Storer in the Oil creek oils, its presence in the Bradford oil furnishing an additional reason for supposing it to be a fractional distillate produced under great pressure, and consequently at a comparatively high temperature.

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a S. F. Peckham, P. A. P. S., x, 453. *b* C. R., xlvii, 646. *c* Communication to S. F. Peckham.

Plate II.

DRAWING OF A PORTION OF THE SURFACE OF A HORSE OF SANDSTONE FOUND ENCLOSED IN THE GRAHAMITE VEIN RITCHIE CO. W.Va. SHOWING THE MANNER IN WHICH THE GRAHAMITE CLEAVES FROM THE ENCLOSING ROCK.

Chapter VI.—THE DEVELOPMENT OF OIL TERRITORY.

In 1858 and 1859, just before Drake obtained oil in his well, the region now known as the "oil region" was an almost unbroken forest. Here and there along the valleys of the Allegheny and its tributaries the bottom-lands had been broken into farms, but on the hills, excepting in the neighborhood of the larger towns, there were but few cultivated tracts. The landscape along these winding streams was very beautiful. The towns were but little more than lumbering camps and trading stations, with few churches or school-houses, and the stores were for the most part kept by those engaged in the lumbering business, who employed nearly the entire population. This population traded a large proportion of the value of their earnings at the stores, and when the yearly settlements came they found a small balance due them. Those who were not engaged in rafting the lumber to Pittsburgh worked their small farms in summer and raised the small amount of produce required in the country, but in the winter lumbering was the engrossing occupation. Off the valleys of the main streams the roads were few and wretchedly poor. A few farms on the bluff southwest of Titusville had been occupied since 1798, and yet no public road had been built until some time after 1860.

After Drake's well was drilled, a demand arose for barrels and teams to haul the oil to points of shipment. This quiet and secluded region was invaded by adventurers from every direction, and the production of oil increased in volume so much more rapidly than the means of gathering and transportation that, although the production for the whole year of 1861 was only 1,035,668 barrels, less than the production of two weeks in 1880, the price fell in the fall of that year to 10 cents per barrel, and sales were reported as low as 6 cents per barrel. The influx of such an immense population into the villages and hamlets of this region taxed its agricultural resources to the utmost, and the construction of countless derricks, and the towns that were springing up like mushrooms along Oil creek and the Allegheny river, the making of tanks and thousands of barrels for storing and transporting the oil, gave a home market for the lumber of the country and stimulated an activity in business before unknown. Land along the creek supposed to be favorable for drilling purposes commanded fabulous prices; everybody had an interest in an oil-well; fortunes were suddenly made in one day and recklessly lost in another; and although railroads were pushed toward Titusville as rapidly as possible, the oil reached the surface faster than it could be disposed of, and was floated down the Allegheny river to Pittsburgh in bulk barges, many of which were broken up in the accidents of such navigation and the contents poured upon the stream. The valley of Oil creek became filled with derricks, and by 1863 the oil territory was supposed to be defined, when a daring prospector, having drilled a "wild-cat" well on the hills that border the valley, got oil, and wells were then spread over the hill country between Titusville and Tidioute. Meantime trunk lines had reached the valleys of the Allegheny and Oil creek, and the oil was moved out of the country.

The development of oil territory had mean time acquired a habit which has become well defined, and has been repeatedly exemplified during the last fifteen years. Commencing with the sinking of test or "wild-cat" wells outside the limits of any proved productive territory, the progress of such wells is eagerly watched, not only by those who pay for them, but also by many others who hope to profit by the experiment. While the experiment is in progress frequently all sorts of devices are resorted to to deceive others, not only to enable those engaged in the experiment to secure all the adjacent territory at favorable prices or leases, but also to prevent others from doing the same thing.

The striking of oil in a new well is the signal for a grand rush, as those who have territory to dispose of express extravagant opinions regarding the yield of the wells and the extent of the territory. A quiet country village at once becomes the center of a large business. Teams come pouring in with oil-well supplies, lumber, and provisions; a narrow-gauge railroad is projected and built with astonishing rapidity; corner lots are sold at fabulous prices; a speculative population floats into the place, the individuals of which come and go; and a common laborer to-day becomes a month hence a foreman, and in six months the owner of a well, and after a year is a gentleman of fortune. The quiet country town, too, with its modest school-houses and churches, takes on metropolitan airs and vices, and farmers become money-changers, the lucky ones who "strike ile" and do not lose their heads usually gathering together their thousands and leaving the overgrown village for New York or some other city. Some few remain and help to permanently improve the home of their childhood. Titusville, Oil City, Tidioute, Franklin, and Bradford are all examples of such towns. After a time the speculative phase is succeeded by that of settled and steady development, and the oil territory becomes outlined, the sagacious having secured control of the profitable tracts, and the floating population having by this time passed on to a new field, while their places have been filled by a more solid element, largely the moderately successful, because less reckless, who have come to stay. The influence of the floating and unsettled class is seldom salutary. In one instance that has been brought to my notice the most reckless system of public improvements was undertaken. School-houses greatly larger and more expensive than

were necessary were built, and instead of being paid for by taxes levied on the oil that was then being taken from the ground, bonds were issued, payable at some future day, and left as a burden upon a community the extraordinary resources of which have long since been removed.

The development of the oil territory proceeds, after its existence has been demonstrated, without regard to any other interest. The derrick comes like an army of occupation. In the towns a door-yard or a garden alike surrender its claims. The farms, fields, orchards, or gardens alike are lost to agriculture and given to oil, and on the forest-covered hills the most beautiful and valuable timber is ruthlessly cut and left to rot in huge heaps wherever a road or a derrick demands room. Pipe-lines are run over the hills and through the valleys, through door-yards, along streets, across streets and railroads, and here and there the vast storage-tanks stand, a perpetual menace to everything near them that will burn. Nothing that I ever beheld reminded me so forcibly of the dire destruction of war as the scenes I beheld in and around Bradford at the close of the census year; and nothing else but the necessities of an army commands such a complete sacrifice of every other interest or leaves such a scene of ruin and desolation.

But the wave of desolation passes over, and nature changes the scene in the same manner as she gathers and restores the ruins of battle-fields. Along Oil creek, for the most part, the derricks have disappeared, and the brambles and the young forest are fast removing even a trace of their former presence. A visit to the famous Pithole City, which in 1865 was, next to Philadelphia, the largest post-office in Pennsylvania, showed a farmer plowing out corn where the famous Shearman well had been, a waving field of timothy where the Homestead well had been, the site of the famous United States well hardly to be found by one who had known it all through its career, and of the city there remained but fifteen or twenty houses, rapidly tumbling to decay, but not an inhabitant. The country around this scene of so much activity fifteen years ago is growing up to forest, and is not now valued at an amount equal to a year's interest on the valuation of that time.

Between the period of active development and absolute exhaustion comes the period of decay, when the derricks are rotting and falling to wreck, when property that has ceased to be productive has been sold at an extravagant price, and after accumulating debts has been abandoned. No one dares to claim the engine, boiler, and other tools, for fear he may become liable for the debts. Fine-engines go to ruin, and boilers are eaten with rust; small boys and idle men throw tools and pebbles in the well, and finally the vender of old iron comes along and carries off the junk to the foundery. At other times the owners of the well have made strikes somewhere else; and the well is then "pulled out" and all the machinery is carried to another field. Enormous quantities of material were carried from Oil creek to Clarion and Butler counties, and from there to the Bradford district.

The Oil creek region has now returned to the condition of an agricultural and manufacturing community, in which the production of oil is no longer the absorbing topic of conversation and the paramount interest. On the lower Allegheny, in Clarion and Butler counties, the production of oil has become much lessened in importance, and the wreck of abandoned derricks in many localities presents a dismal picture. The Bradford field is now in fully developed activity, and the destructive subordination of every other interest, and of all other considerations of ordinary value, is everywhere painfully apparent. With all this there is an evidence that so-called public improvements are only of a temporary character. The towns that are the result of the production of oil are scarcely more substantial than a military camp, and from lack of orderly arrangement, neatness, and sanitary regulations are far less inviting in their appearance. The railroads remind one forcibly of those built around Petersburg during the war, although they possess the elements of permanency to a greater degree, and the destruction of so much valuable timber produces a melancholy aspect.

The Allegheny district in New York is just opening up around Richburg, and all the phenomena peculiar to the first stages of an oil excitement are to be observed there.

It is not to be inferred, however, that any of the sections into which the oil regions have been divided have ceased to produce oil. There are wells now producing in sight of the spot where Drake drilled the first well; but large tracts of country cease to be the centers of speculative investment, and old wells to be remunerative, and the new wells no longer hold the possibilities of a grand lottery prize. It is the opinion that large areas in the Oil creek district will be redrilled and will produce in the aggregate large quantities of oil if the price ever reaches $2 a barrel. At present prices, the pumping wells of that district cannot successfully compete with the flowing wells of McKean county.

CHAPTER VII.—THE PRODUCTION OF OIL.

SECTION 1.—PRIMITIVE METHODS.

Oils and malthas appear to have been obtained in Persia from a very early period, but the methods employed were extremely simple. Most frequently the basin of the spring appears to have been surrounded by a stone coping, and sometimes it was covered with some sort of a niche or building, but often the oil was simply skimmed from the surface of the water which it accompanied. Herodotus describes the manner in which, by means of myrtle branches, the bitumen was obtained from the springs in Zacynthus, now Zante. It is, however, by means of dug wells or shafts that petroleum has been usually obtained in regions where the art of drilling artesian wells was unknown.

In Japan from a very remote period wells have been dug and tunnels have been run into hillsides for oil. Some of these abandoned drifts have caved in and large trees are growing upon them.

In relation to the manner of working these wells, B. S. Lyman, in his *Reports on the Geology of Japan*, 1877, says:

The present mode of working is very simple, a method that has probably grown into its present form in the course of centuries of experience, and is now apparently practiced in all the oil regions with little or no variation. The digging is all done by two men, one of whom digs in the morning from nine o'clock until noon, and the other from noon until three. The one who is not digging works the large blowing machine or bellows that continually sends fresh air to the bottom of the well. The blowing apparatus is nothing but a wooden box about 6 feet long by 3 wide and 2 deep, with a board of the same length and width turning in it upon a horizontal axis at the middle of each long side of the box, and with a vertical division below the board between the two ends of the box. The workman stands upon the board and walks from one end of it to the other, alternately pressing down first one end and then the other. At his first step on each end he gives a smart blow with his foot, so as to close with the jerk a small valve (0.3 foot square) beneath each end of the board, a valve that opens by its own weight when the end of the board rises. The air is therefore driven first from one end of the box, then from the other into an air pipe about 0.8 foot square, provided at top, of course, with a small valve for each end of the blowing-box, made of boards in lengths of about 6 feet, and placed in one corner of the well. The well is, besides, timbered with larger pieces at the corners and light cross-pieces, which serve also as a ladder for going up and down, though at such a time, in addition, a rope is tied around the body under the arms and held by several men above the mouth of the well. The earth or rock dug up is brought out of the well in rope nets by means of a rope that passes over a wheel 1 foot in diameter, hung just under the roof of the hut, about 10 feet above the mouth of the well, and is pulled up by three men, one at each corner of one side of the well, and the third in a hole two or three feet deep and a foot and a half wide dug along side of the well. * * * Wells are dug in this manner to a depth of from 600 to 900 feet, a depth at which great difficulty is experienced in securing sufficient light to carry on the work, which is often prosecuted only from nine a. m. to three p. m. These wells are dug about 3½ feet square. One well 900 feet deep is reported to have cost only about $1,000. The oil is skimmed from the surface of the water and drawn up in buckets.

In a letter dated Toungoo, British Burmah, September 14, 1881, Rev. J. N. Cushing, D. D., says:

At Yenangyoung the construction of the wells is after the most primitive method. The wells are dug about 5 feet square. A native spade for loosening the soil and a basket for conveying it from the well are the implements used. As fast as the well is sunk it is planked up with split, not sawed, planks. There are generally three or four men engaged in the work of digging, each one taking his turn. A man remains below with a large rope fastened about him. A small rope attached to a basket is used to draw up the earth, which is saturated with oil, and is often quite warm to the touch. Sometimes the gas is so strong as to prevent a person from remaining below more than a couple of minutes, and occasionally a man is drawn up quite insensible The usual time of remaining down is about twenty minutes, when the man gives the signal that he wishes to be drawn up by jerking the rope. The yield is seldom very rapid, as I have never heard of any petroleum rising to the surface. Still some of the wells yield a large amount and then dry up. A windlass is built upon a frame over the well at a height of about 5 feet from the mouth. Over this windlass a rope is placed having a bucket at one end. The rope is not much longer than the depth of the well. The other end is fastened around the waist of a man or a woman, who generally has two or more half-grown boys or girls to help pull. As soon as the bucket fills, these persons start on a run down a well-beaten path until the bucket has come up so that the person standing by the well can empty it. The work is done by a class of people whose families have been allotted this work from time immemorial by the royal law. They are not slaves, but do not have permission to remove, and are considered as bound to work for the production of the royal monopoly.

In Galicia wells were dug as for water, and in some instances congeries of wells were united at the bottom by galleries, into which the petroleum filtered from the rock. The digging of these wells and shafts was frequently attended with considerable danger of suffocation with gas. M. Coquand mentions that at Damanostotin, in Moldavia, the pits or wells were dug 40 meters (131.2 feet) deep, and lined with sticks, woven in a manner resembling a military gabion. The petroleum is obtained in a bucket, to which a stone is attached for a sinker. This bucket is drawn up by a rope. (*a*) Petroleum was also obtained for many years in the valley of the Po from wells that were dug.

In the United States several different methods for obtaining oil were employed before wells were drilled. It is reported that shafts were found in the Mecca (Ohio) oil district, of the sinking of which all record or tradition has been lost. Since the curbed pits on Oil creek, Pithole creek, and other tributaries of the Allegheny have been proved to be of French origin, it is not unlikely that the old shaft at Mecca was also made by the French. An unsuccessful attempt to obtain oil in this way was made at Mecca about 1864, and another attempt to sink a shaft to the Venango oil-sand was made in 1865 in the bend of the Allegheny river, on the east side, below Tidioute.

It was about 16 feet square and a little over 100 feet in depth. It was a failure in respect to obtaining oil, for just before it was deep enough to reach the third sand, or oil-producing rock, an accident occurred which resulted in its abandonment. The foreman, who was an experienced miner, was seated over the mouth of the shaft, which was covered, in company with one or two of his laboring men,

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a B. S. G. F., xxiv, 518.

eating their dinner. As they lighted their pipes it was suggested that a lighted paper be dropped into the shaft to see if any gas was there. It was done, and an explosion followed which killed the foreman and some of his men. It [the well] was immediately closed, and work was never resumed. (*a*)

Other shafts were sunk on Oil creek, but as none of them were successful in reaching the Venango third sand, they were abandoned.

Professor Silliman, sr., in 1833, thus described the method employed for obtaining Seneca oil at the famous spring at Cuba:

A broad, flat board, made thin at one edge, like a knife; it is moved flat upon and just under the surface of the water, and is soon covered by a coating of petroleum, which is so thick and adhesive that it does not fall off, but is removed by scraping on the edge of a cup. (*b*)

Near Burning Springs, West Virginia, the oil was collected early in this century "by digging trenches along the margin of the creek down to a bed of gravel a few feet below the surface. By opening and loosening with a spade or sharpened stick the gravel and sand, which is only about a foot thick, the oil rises to the surface of the water, with which the trench is partially filled. It is then skimmed off with a tin cup and put up in barrels for sale. In this way from 50 to 100 barrels are collected in a season". (*c*)

Professor J. P. Lesley thus describes the method employed for collecting oil on Paint creek, Johnson county, Kentucky:

Here are to be seen the old "stirring places", where, before the rebellion broke out and put an end to all manner of trade in Kentucky, Mr. George and others collected oil from the sands by making shallow canals one or two hundred feet long, with an upright board and a reservoir at the lower end, from which they obtained as much as 200 barrels per year by stirring the sands with a pole. (*d*)

J. D. Angier, of Titusville, worked the springs on Oil creek for some years prior to 1859. He found the springs logged up 6 to 8 feet square and as many feet deep. He arranged a sort of sluice-box, with bars, that held the oil while the water flowed on beneath. In this way he obtained from 8 to 10 gallons a day of 36° specific gravity, which he sold at Titusville for medicine and for lighting saw-mills and the derricks of salt-wells.

Seneca oil was obtained for many years and in many localities by saturating blankets with oil and wringing it from them.

Section 2.—ARTESIAN WELLS—THE DERRICK.

ARTESIAN WELLS.

The Jesuit missionaries to China found there artesian wells in full operation. These wells were drilled for brine and natural gas, the latter being frequently accompanied by petroleum. The following extract from L'Abbé Huc's celebrated travels in China describes their method of drilling very deep wells:

They [the wells] are usually from 1,500 to 1,800 (French) feet deep, and only 5 or 6 inches in diameter. The mode of proceeding is this: If there be a depth of 3 or 4 feet of soil on the surface, they plant in this a tube of hollow wood, surmounted by a stone, in which an orifice of the desired size of 4 or 5 inches has been cut. Upon this they bring to work in the tube a rammer of 300 or 400 pounds weight, which is notched and made a little concave above and convex below. A strong man, very lightly dressed, then mounts on a scaffolding, and dances all the morning on a kind of lever that raises this rammer about 2 feet and then lets it fall by its own weight. From time to time a few pails of water are thrown into the hole to soften the material of the rock and reduce it to pulp. The rammer is suspended to a rattan cord not thicker than your finger, but as strong as our ropes of catgut. This cord is fixed to the lever, and a triangular piece of wood is attached to it, by which another man, sitting near, gives it a half-turn, so as to make the rammer fall in another direction. At noon this man mounts on the scaffold and relieves his comrade till the evening, and at night these two are replaced by another pair of workmen. When they have bored 3 inches they draw up the tube, with all the matter it is loaded with, by means of a great cylinder, which serves to roll the cord on. In this manner these little wells or tubes are made quite perpendicular and as polished as glass. * * * When the rock is good the work advances at the rate of 2 feet in twenty-four hours, so that about three years are required to dig a well. (*e*)

The first artesian well drilled in the United States, in 1809, has already been described, as also the gradual improvements in tubing wells and in stopping off the surface water with a seed-bag (page 6). Prior to 1858 a great many wells had been drilled for brine in the valley of the Ohio and its tributaries, with such additional improvements as rendered them very effective for this purpose. Steam-, horse-, and hand-power had been employed in drilling with equal success, the tools and general manipulation of the well being essentially the same. The drilling of wells with hand-power was accomplished by means of a spring-pole. For this purpose a straight tree, forty or fifty feet in length, was selected. After the branches were removed, the butt was secured in the ground in such a position that the pole extended at an angle of about 30° over the spot at which the well was to be bored. To the smaller end the tools were attached, and by the elasticity of the pole, as it was alternately pulled down and allowed to spring back, they were lifted and made to strike at the bottom of the well.

The drilling of wells for oil has long since outgrown the spring-pole age, the figures on Plate VI showing the successive steps by which this has been accomplished.

THE DERRICK.

When the location of a well has been decided upon a derrick or "rig" is built. This consists of the derrick itself and a small house for an engine, with the necessary foundation for both. For this purpose masonry is not used, but instead a very heavy foundation of timber. The owner of the well owns the rig, boiler, and engine. The contractor who drills the well owns the cable, bit, blacksmith's and other tools, and supplies fuel for the engine and the blacksmith.

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a Letter of W. W. Hague, of Tidioute, to S. F. Peckham.

b A. J. S. (1), xxiii, 99.

c S. P. Hildreth, A. J. S. (1), xxix, 86.

d P. A. P. S., x, 40.

e *Travels in the Chinese Empire*, 1,300, Harper's ed., 1855.

The following list of rig-timbers embraces, first, the foundation timbers, which are frequently hewn, and, second, sawed timber. The plan of foundation timbers (Fig. 15) is drawn for square timber, but in a region like the northern field, where the wells are chiefly located in forests, these timbers are often hewn from the trees around the well:

HEWED RIG-TIMBERS.

	Inches.	Feet long.
2 derrick-sills, spotted	12	21
2 derrick-sills, spotted	10	21
2 derrick-sills, flatted	12	21
2 derrick-sills, flatted	10	21
3 mud-sills, faced	16	20
5 mud-sills, faced	16	12
1 main-sill, squared	18 by 18	30
1 sub-sill, squared	18 by 18	14
1 cross-sill, squared	12 by 12	12
1 samson-post, squared	18 by 18	14
1 jack-post, squared	16 by 18	14
2 bull-wheel posts, squared	10 by 10	10
1 engine-block, squared	20 by 20	8
1 walking-beam, squared	12 by 26	26
1 bull-wheel shaft, squared	14 by 14	14
2 pulley-blocks, squared	12 by 12	6
4 braces, squared	6 by 8	14
1 lever, squared	7 by 9	7

Equal to 7,800 feet board measure.

SAWED RIG-TIMBER.

	Inches.	Feet.	Feet.
8 pieces	2 by 10 by	20 =	267
5 pieces	2 by 8 by	20 =	133
6 pieces	2 by 12 by	18 =	216
4 pieces	2 by 10 by	18 =	120
7 pieces	2 by 8 by	18 =	168
8 pieces	1½ by 8 by	18 =	144
4 pieces	1½ by 12 by	16 =	96
18 pieces	2 by 10 by	16 =	480
18 pieces	2 by 8 by	16 =	384
6 pieces	2 by 6 by	16 =	96
25 pieces	2 by 4 by	16 =	267
4 pieces	2 by 6 by	14 =	56
20 pieces	1 by 12 by	16 =	320
20 pieces	1 by 8 by	16 =	213
20 pieces	1 by 7 by	14 =	245
2-inch plank, 20 feet long			800
1-inch boards, 14 feet long			500
1-inch boards, 16 feet long			4,500
			9,005

The foregoing dimension timbers may be either pine or hemlock, the latter being used almost exclusively at the present time:

HARD-WOOD LUMBER (OAK OR MAPLE).

	Inches.	Feet.	Feet.
7 pieces	2 by 8 by	16 =	149
1 piece	2 by 12 by	12 =	24
			173

Hewed timber	7,800
Sawed lumber	9,005
Hard lumber	173
	16,978

Total, 17,000 feet of lumber for a rig.

To put the rig together requires—

	Pounds.
10-penny nails	150
20-penny nails	25
30-penny nails	125
40-penny nails	10
	310
Bolts	13
Strap-hinges ....pair..	1

If the wheels for reeling the cable and sand-pump rope are not purchased separately, but are made with the derrick, there will be required:

32 arms for 2 bull-wheels.
104 cants of 3 feet 9 inches radius for 2 bull-wheels.
32 cants of 4 feet 6 inches radius for band-wheel.
8 cants of 3 feet 3 inches radius for tug-pulley.

HARDWARE (RIG-IRONS).

1 walking-beam stirrup, 2⅝ inches by ⅝ inch.
4 bolts for securing the same by a wooden cap to the walking-beam.
2 boxes for band-wheel shaft, babbitted, and each with 4 bolts.
1 band-wheel shaft 4 feet 6 inches long, 3½ inches diameter, with 1 crank, 14 to 46 inches stroke, 6 holes; 1 wrist-pin, 2⅝ inches diameter; 2 flanges, 24 inches diameter; 2 flanges, 20 inches diameter; 12 flange-bolts, 7 inches long, ⅝ inch diameter; 5 steel keys for flanges and crank; 1 collar and set screw (not always used).
1 saddle for walking-beam.
4 bolts for same.
2 side irons, boxes and bolts for samson-post.
1 derrick-pulley, 20 inches in diameter.
1 walking-beam hook, to hold temper-screw.
1 sand-pump pulley.
2 gudgeons, with bands, for bull-wheel.

The derricks require each about thirty days of skilled and ten days of ordinary labor. During the census year they cost from $325 to $400, according to the cost of getting the materials to the place where the rig was to be built. At the same time a set of "rig-irons" cost from $75 to $100. A rig for winter use must be closed in, and therefore requires a larger outlay for 1-inch lumber. The increased expense, however, amounts to only a small sum.

Figs. 16, 17, and 18 represent plans and elevations of a full oil-well rig. As originally drawn, they were prepared by H. Martyn Chance from working plans furnished by J. F. Carll. They exhibit in great detail the construction of a "rig" suitable for drilling a well from 2,500 to 3,000 feet in depth. The following description is abridged from the report of the *Second Geological Survey of Pennsylvania*, Report III:

The mud-sills *a* (Fig. 15) are generally sunk in trenches where the nature of the ground admits of its being done. They have gains cut into them to receive the main sill *d* and sub-sills *e* and *e'*. After all have been put in place and leveled up, the keys or wedges *h* are driven, and the whole foundation is thus firmly locked together. The samson-post *k* and jack-posts *l*, *s*, and *r* are dovetailed into the sills and held by properly fitted keys, *h*, as seen in the side elevation (Fig. 16). The braces are all set in gains and keyed up, *no mortises and tenons being used in the structure*, the advantages of which are (1) greater strength; (2) the keys can be driven to compensate shrinkage; (3) the posts and braces are easily put in line and kept there; (4) the whole is easily taken apart for removal.

Referring to the horizontal projection (Fig. 17), it will be observed that the samson-post is placed flush with one side of the main sill, and the band-wheel jack-post is put flush with the other side. In this way the walking-beam will run parallel with the main sill. If the main sill is less than 24 inches wide, these posts must, in order to get a bearing upon it, be set toward the center of the sill, the effect of which will be to throw the derrick end of the walking-beam to one side of the center of the derrick, and thus throw the engine and running-gear out of line with it.

If, therefore, the main sill be less than 24 inches wide, it should be placed in position and the point marked on it where the center of the samson-post is to come; then mark also the point on which a perpendicular will fall from the center of the wrist-pin. The dimensions of samson-post and band-wheel irons, with the length of the walking-beam, easily furnish these points, through which a chalk-line should be snapped, and all the work squared to this line. This throws only the main sill out of square with the other work. On this account a slightly crooked stick is found serviceable for a main sill.

A great variety of boilers are used, but the one in general use is a tubular boiler constructed very nearly on the plan of a locomotive boiler. Formerly the boiler was set up in the engine-house, frequently with the engine bolted on the top or side of it, or the whole thing was mounted on wheels; but the heavy drilling tools employed in the deep wells now drilled render a stationary engine necessary. The plan of drilling dry wells, now so universal, has been accompanied with so many fires and explosions by the ignition of gas at the boiler that prudence has caused the boiler to be removed to some distance from the engine and well. When near the oil-rock, it is now customary to remove both boiler and forge from near the derrick until the gas and oil are under control. A large boiler, centrally located, is sometimes used to supply steam to the engines of several wells that are being drilled simultaneously.

A 12 or 15 horse-power engine, *b'*, with a reversible movement, is bolted to the engine-block *b* (Fig. 16), and by means of its driving-pulley carrying-belt, *o o*, communicates motion to the band-wheel *m*, and through it to all parts of the machinery. The throttle-valve *l l* is operated by a groove vertical pulley. From this pulley an endless cord, called "the telegraph", extends to the derrick and passes around a similar pulley, *n n*, fixed upon the headache-post *z*, within easy reach of the driller. The driller has thus an easy control over the throttle-valve, and can stop and

start the engine or increase or decrease its speed without leaving his position (Fig. 16). The reverse link *pp* is also operated from the derrick by the cord *q q*, which passes over two pulleys, one of which is fixed in the engine-house and the other on the derrick. A slight pull raises the link and reverses the motion, which is restored as soon as the cord is released and the link drops back.

The band-wheel *m* receives its motion direct from the driving-pulley of the engine, to which it is connected by the belt *o o*. On or near the end of its shaft *o* is the bull-rope pulley *n*, and upon its other end is the crank *o'*. This crank has six holes to receive an adjustable wrist-pin *p*, which is easily moved from one hole to the other to regulate the length of stroke required in drilling or pumping. As the band-wheel communicates motion through the pitman *q* to the walking-beam while drilling; to the bull-wheels, by the bull-rope *r r*, while running up the tools; and to the sand-pump reel, by the friction pulley *w*, while sand-pumping, all of which movements are used separately, the machinery is so constructed that the connections may be rapidly made and broken. The sand-pump reel *w* is put in motion by pressing on the lever *v*, which is joined by the connecting-bar *u* to the upright lever *t*. This brings the face of the beveled pulley *w* into contact with the face of the band-wheel. The sand-pump descends by gravity and is checked in its motion by pressing the lever *v* back in such a manner as to throw the friction-pulley *w* against a post, which acts as a brake. The sand-pump line is a cable-laid rope, seven-eighths of an inch in diameter, and is coiled upon the shaft *x*, from which it passes over the pulley *i i*, and thence to the well mouth. The most common sand-pump is a plain cylinder of light galvanized iron, with a bail at the top and a stem-valve at the bottom. It is usually 6 feet long, but is sometimes 15 or 20 feet in length. As the valve-stem projects downward a few inches beyond the bottom, it is only necessary to let it rest on the bottom of the waste-trough in order to empty it. Other forms of sand-pumps are more complicated in construction.

The walking-beam connections cannot be interrupted without stopping the engine. When disconnected, it is tipped at an angle of about 25°, which throws the derrick end back about a foot from its perpendicular over the well, and thus removes it from interference with cables, tools, sand-pumps, etc., as they are run up and down. The headache-post receives the walking-beam in case the wrist-pin should break or the pitman fly off. It is about 8 inches in section, and is placed on the main sill, directly under the walking-beam, in such a manner that in case of accident the walking-beam can fall only a few inches. (*a*) Fig. 19 shows the interior of a closed derrick at night, with the use of the temper-screw and derrick light.

SECTION 3.—THE DRILLING-TOOLS.

The illustrations given in this report are only those of the ordinary drilling-tools. The tools used for "fishing" other tools, broken or lost anywhere from 100 to 2,000 feet from the surface, are too numerous even for mention. These tools are of all kinds, from the delicate grab, designed to pick up a small piece of valve-leather or a broken sucker-rod rivet from the pump-chamber, to the ponderous string of "pole-tools" containing tons of iron, which, at a depth of 1,500 feet or more, can unscrew a set of "stuck tools" and bring them up piece by piece, or cut a thread on the broken end of a sinker-bar or an auger-stem, to which tools can be screwed fast, so that it may be loosened by the use of "whisky jacks" at the surface. (*b*)

A string of drilling-tools is represented together in Fig. 5, Plate VI, and separately in Figs. 20 to 30. The string weighs about 2,100 pounds, and consists of two parts, separated by the jars. The lower portion, or drill, that delivers its blow downward and cuts the rock, consists of the bit (Figs. 20 and 21), the auger-stem (Fig. 22), and the lower half of the jars (Fig. 23). The upper portion that delivers its blow upward consists of the upper portion of the jars (Fig. 23), the sinker-bar (Fig. 24), and the rope-socket (Fig. 25). The upper link of the jars, by delivering an upward blow upon the auger-stem and bit, prevents the bit from sticking and remaining fast, while the elasticity of the cable permits the motion of the walking-beam. The "jars" therefore become the center of importance as well as of action. They were invented in 1831 by Billy Morris, but were never patented. Fig. 23 shows a pair of jars closed and another opened, with cross-sections. They are made like two flat links of a chain, with a male screw attached to one link and a female screw attached to the other. The slots in the links are each 21 inches long, and the cross-heads 8 inches deep; there is, therefore, 13 inches of "play" to the jars.

J. F. Carll, in Report III, *Second Geological Survey of Pennsylvania*, page 299 *et seq.*, says:

The manner in which the jars perform their work may be best explained, perhaps, in this way: Suppose the tools to have been just run to the bottom of the well—the jars closed as in *a*, Fig. 23—the cable is slack. The men now take hold of the bull-wheels and draw up the slack until the sinker-bar rises, the "play" of the jars allowing it to come up 13 inches without disturbing the auger-stem. When the jars come together they slack about 4 inches, and the cable is in position to be clamped in the temper-screw. If, now, the vertical movement of the walking-beam be 24 inches when it starts on the up-stroke, the sinker-bar rises 4 inches and the cross-heads come together with a smart blow, then the auger-stem is picked up and lifted 20 inches. On the down-stroke the auger-stem falls 20 inches, while the sinker-bar goes down 24 inches to telescope the jars for the next blow coming up. A skillful driller never allows his jars to strike on the down-stroke. They are only used to "jar down" when the tools stick on some obstruction in the well before reaching the bottom and in fishing operations. An unskillful workman sometimes "looses the jar" and works for hours without accomplishing anything. The tools may be standing on the bottom while he is playing with the slack of the cable, or they may be swinging all the time several feet from the bottom. If he cannot recognize the jar, he is working entirely in the dark; but an expert will tell you the

a J. F. Carll, Rep. III, *Sec. Geo. Surv. Penna.*, chap. xvii. *b* *Ibid.*, p. 298.

moment he puts his hand upon the cable whether the drill is working properly or not. As the "jar works off", or grows more feeble, by reason of the downward advance of the drill, it is "tempered" to the proper strength by letting down the temper-screw to give the jars more play.

The temper-screw, Fig. 26, forms the connecting link between the walking-beam and cable, and it is "let out" gradually to regulate the play of the jars as fast as the drill penetrates the rock. When its whole length is run down, the rope clamps play very near the well mouth. The tools are then withdrawn, the well sand-pumped, and preparations made for the next "run". With the old-fashioned temper-screw a great deal of time was spent in readjustment, for it had to be screwed up by tedious revolutions of the clamps. But this delay is now obviated. The nut through which the screw passes is cut in halves, one half being attached to the left wing of the screw-frame, the other half to the right wing. An elliptical band holding the set-screw *a* passes around the nut. It is riveted securely to one of the halves, and the set-screw presses against the other half to keep the nut closed. The wings *b b* are so adjusted that they spring outward and open the nut whenever the set-screw is loosened. To "run up" the screw the driller clasps the wings in his left hand and loosens the set-screw; he then seizes the head of the temper-screw in his right hand, and, relaxing his grip upon the wings, the nut opens, when he quickly shoves the screw up to its place, again grips the wings and tightens the set-screw.

The dimensions of the different tools required to make up a set are given in the figures that represent them. The lengths of the different parts are given below:

	Feet.	Inches.
Rope-socket	3	6
Sinker-bar	18	0
Jars	7	4
Auger-stem	30	0
Center-bit	3	3
	62	1

The wings of the temper-screw are 1½ inches by ⅝ inch, and 4 feet 6 inches long. The screw is 1⅜ inches in diameter and 4 feet long, with two square threads to the inch. The weight of the string of tools is as follows:

	Pounds.
Fig. 25.—Rope-socket	80
Fig. 24.—Sinker-bar, 3½-inch	540
Fig. 23.—Jars, 5½-inch	320
Fig. 22.—Auger-stem	1,020
Fig. 21.—Bit	140
	2,100

The other tools weigh as follows:

	Pounds.	
Fig. 26.—Temper-screw	145	
Fig. 23.—Jars, 8-inch	565	
Fig. 20.—Two bits, 8-inch	320	
Fig. 30.—Reamer	180	
Fig. 21.—Two bits, 5½-inch	280	
Fig. 29.—Reamer, 5½-inch	140	
Fig. 27.—Ring-socket	50	
Fig. 28.—Two wrenches	210	
		1,890
Total weight of set		3,990
Total cost of set		$700
Driller's complete outfit, including cable, costs about		900

These tools are made of the best of steel and Norway iron.

Section 4.—DRILLING WELLS.

By reference to Chapter I, page 6, it will be observed that the Ruffner Brothers "provided a straight, well-formed, hollow sycamore tree, with 4 feet internal diameter, sawed off square at each end". This was placed on end, and by digging out beneath it was gradually sunk to the bed-rock. This device was in time replaced by a smaller conductor, that was placed in the center of a sort of shaft or well that was dug (when practicable) to the bed-rock. This conductor was made of two-inch plank spiked together, 6 or 8 inches square on the inside, and placed in position vertically beneath the center of the derrick floor, as shown in Fig. 1, Plate VI, and Fig. 31. When the bed-rock is below a depth to which it is practicable to dig, an iron pipe is driven to the rock (shown in Fig. 3, Plate VI, and Fig. 33). When the "drive pipe" is to be inserted a "mall" and "guides" must be provided. This mall is made of any tough, hard log that will dress 15 to 18 inches square and 10 or 12 feet long. Two sides only are dressed, one end being encircled by a heavy iron band, to prevent its splitting, the other having a strong staple driven into it, in which to tie the cable. Two pairs of wooden pins are put into each of the dressed sides, one pair near the top, and the other near the bottom. They are two inches apart and two inches long, the guides fitting between them. The guides consist of two 2-inch planks, placed perpendicularly upon a line drawn through the center of the well at right angles to the walking-beam, and 15 or 18 inches apart. They are securely stayed and strengthened by having narrower plank nailed on both sides of them, leaving their edges projecting 2 inches toward each other, to enter between the pins on the mall.

Plate VI.

PUMPING WELL 1861. PUMPING WELL 1868. PUMPING WELL 1878. FLOWING WELL 1880. DRILLING WELL AND FULL STRING OF TOOLS.

Scale

Oil

Water

to enter between the pins on

The well is started by spudding. To do this a short cable is run up over the crown pulley in the top of the derrick. One end is attached to the ring-socket (Fig. 27) and screwed to the auger-stem; the other is passed around the bull-wheel shaft two or three times and the end left free. The bull-rope is now put on and the engine started. A man in front of the bull-wheels seizes the free end of the rope coiled around the shaft, a slight pull causes the coils to tighten and adhere to the revolving shaft, and the auger-stem rises in consequence, until it hangs suspended on the derrick, when it is swung over the spot where the well is to be started. The engine is kept running and the bull-wheels continue to revolve, but the man holding the shaft-rope has full control of the tools. When he pulls on the rope the coils at once "bite" the revolving shaft and the tools rise; but when he gives his rope slack they fall, and so long as the coils remain loose upon the shaft it revolves smoothly within them and communicates no motion. Thus, by alternately pulling and slacking the rope, this animated substitute for a walking-beam raises and drops the tools as much or as little as may be required, while the driller turns the drill to insure a round hole.

After spudding awhile to prepare the way for the drive-pipe, the drill is set aside, and the pipe to be driven, armed at the bottom with a steel shoe, as shown in Fig. 3, Plate VI, is put in place.

The following graphic description of the drilling of a well is given by J. F. Carll, in Report III, *Second Geological Survey of Pennsylvania*, page 306:

The mall is attached to the spudding cable and let down between the guides, where it is alternately raised and dropped upon the casing or drive-pipe by the man at the bull-wheels, precisely the same as in spudding. The casing used is of wrought-iron, screwed together in thimbles the same as tubing. A heavy cap of iron is screwed in the top when driving, to prevent its being injured by the blows of the mall.

When two or three hundred feet of pipe are to be driven, as is frequently the case in some of our northern valleys, it requires a great deal of skill and judgment to put it in successfully. In these deep drivings, after a sufficient depth has been reached to admit of the introduction of a string of tools, they are put in and operated by the walking-beam in the usual way; the cable (a short one, furnished for the purpose) being coiled upon one end of the bull-wheel shaft, while the other end is left free to work the mall-rope on.

To facilitate the necessary changes, which must be made every time the drill is stopped and pipe driven, the lower part of the guides are cut and hung on hinges some 10 or 12 feet above the derrick floor, and when not in use may be swung up overhead out of the way of the workmen.

When a sufficient depth has been reached by spudding to admit of the introduction of a full "string of tools", the spudding machinery is abandoned.

Now the coil of drilling cable is rolled into the derrick and set upon end. The free end in the center of the coil is tied by a connecting cord to the rope just detached from the ring-socket, and by it drawn up over the crown-pulley and down to the bull-wheel shaft, where it is fastened; the bull-rope is put in place, the engine started, and the men carefully watch and guide the cable as it is wound, coil after coil, smoothly and solidly upon the shaft. When this is done the end of the cable depending from the crown-pulley is secured to the rope-socket, and the full set of tools is attached and swung up in the derrick. After carefully screwing up all the joints (the bull-rope having been unshipped), the tools (Fig. 5, Plate VI) are lowered into the hole by means of the bull-wheel brake *c c*, shown in Fig. 16. The band-wheel crank is then turned to the upper center; the pitman is raised and slipped upon the wrist-pin, where it is secured by the key and wedges; the temper-screw is hung upon the walking-beam hook; the slack in the cable is taken up by the bull-wheels until the jars are known to be in proper position; the clamps are brought around the cable (after a wrapper has been put on it at the point of contact) and securely fastened by the set-screw; the cable is slacked off from the bull-wheels, and the tools are now held suspended in the well from the walking-beam instead of from the top of the derrick, as before. Some fifteen or twenty feet of slack cable should be pulled down and thrown upon the floor to give free movement to the drill. When the drill is rotated in one direction for some time the slack coils around the cable at the well mouth; if it becomes troublesome, the motion is reversed and it uncoils. Only by this constant rotation of the drill can a round hole be insured.

Having now made all the necessary connections, it only remains to give the engine steam, and the drill will rise and fall with each revolution of the band-wheel and commence its aggressive work upon the rock below. From this point downward the daily routine of the work is very monotonous unless some accident occurs to diversify it. Day and night the machinery is kept in motion. One driller and one engineer and tool-dresser work from noon until midnight (the "afternoon tour"), and another pair from midnight until noon (the "morning tour"). Up and down goes the walking-beam, while the driller, with a short lever inserted in the rings of the temper-screw, walks round and round, first this way, then that, to rotate the drill. He watches the jar, and at proper intervals lets down the temper-screw as the drill penetrates the rock. When the whole length of the screw has been "run out", or the slow progress of the drill gives warning that it is working in hard rock and needs sharpening, he arranges the slack cable upon the floor so that it will go up freely without kinks, and informs the engineer that he is ready to "draw out".

After attending to the needful preliminaries, the driller throws the bull-rope upon its pulley, and quickly steps to the bull-wheel brake, while the engineer commands the throttle of the engine. The walking-beam and the bull-wheel are now both in motion, but at the proper moment one man stops the engine and the other holds the bull-wheels with the brake just when all the slack cable has been taken up, and the weight of the tools is thus transferred from the temper-screw to the crown-pulley.

This is a performance requiring experience and good judgment, for should any blunder be made a break-down must certainly result. To loosen the clamps on the cable and unlock the pitman from the wrist-pin and lower it to the main sill is but the work of a moment. Dropping the pitman raises the end of the walking-beam with the temper-screw attached to it and throws them back from their former perpendicular over the hole, so as to allow the cable and tools to run up freely without interference with them. Steam is now turned on again, and the tools come up. When the box of the auger-stem emerges from the hole the engine is stopped. A wrench is slipped on the square shoulder of the bit, and the handle dropped behind a strong pin fixed for that purpose in the floor; another wrench is put on the shoulder of the auger-stem; a stout lever is inserted in one of the series of holes bored in the derrick floor in a circle having a radius a little less than the length of the wrench-handle, and it is brought up firmly against the upper wrench-handle, thus making a compound lever of the wrench and greatly increasing its power. Both men give a hearty pull on the lever, which "breaks the joint", or, in other words, loosens the screw-joint connecting the bit with the auger-stem, so that the bit can be unscrewed and taken off by hand after it has been brought up above the derrick floor. The wrenches are then thrown off, steam is let on again, and the bit rises from the hole. Now the driller throws off the bull-rope by operating a lever with one hand, while with the other he catches the bull-wheel with the brake, holding

the tools suspended a few inches above the derrick floor. At the same instant the engineer shuts off the steam, or else, suddenly relieved of its heavy work by unshipping the bull-rope, the engine would "run away" with lightning speed. It only remains now to hook the suspended tools over to one side of the derrick, and the hole is free for the sand-pump.

While the driller is sand-pumping the engineer unscrews the worn bit and replaces it by one newly dressed, so that there may be no delay in running the tools into the well again when sand-pumping is ended.

The "line" to which the sand-pump is attached (as before described) passes up over a pulley near the top of the derrick, and thence down to the sand-pump reel, which is operated from the derrick by means of hand-lever *v* and connecting levers *u* and *t*. While sand-pumping the pitman remains disconnected, the bull-rope lies slack on its pulleys, and the band-wheel is kept constantly in motion. A slight pressure on lever *v* brings the friction-pulley *w* in contact with the band-wheel, and the pulley immediately revolves, the slack sand-pump line is quickly wound up, and the sand-pump, which is usually left standing at one side of the derrick, swings out to the center and commences to ascend. Just now the lever is thrown back, and the connection between the friction-pulley and the band-wheel being thus broken, the sand-pump commences to descend into the well by its own gravity. If it be likely to attain too great speed in its descent, a movement of the lever to bring the pulley either forward against the band-wheel or backward against the brake-post will quickly check it, and thus the speed may be regulated at will.

As soon as the pump strikes bottom additional steam is given to the engine, and the lever is brought forward and held firmly, while the sand-pump rises rapidly from the well. The sand-pump is usually run down several times after each removal of the tools, to keep the bottom of the hole free from sediment, so that the bit may have a direct action upon the rock.

After the hole has been sufficiently cleansed, the sand-pump is set to one side, the drilling tools are unhooked, and, swinging to their place over the well mouth, are let down a short distance by the brake, the wrenches are put on, and the lever is applied to "set up" the joint connecting the replaced bit to the auger-stem. Then removing the wrenches, the tools are allowed to run down to the bottom under control of the bull-wheel brake. Connections are now made as before, the driller commences his circular march, the engineer examines the steam- and the water-gauges and the fire, and then proceeds to sharpen the tool required for the next "run", and thus the work goes on from day to day until the well is completed.

The derrick and other apparatus here described is that employed in the oil regions of Pennsylvania, where the wells are deep and the tools required for drilling them are heavy. In the Franklin, Mecca, and Belden districts the shallow wells require a comparatively simple and inexpensive apparatus, the derricks being often not more than 30 feet in height, and the entire cost of a well only about $300. In West Virginia and southern Ohio the "light rigs" of the early time are still largely used, but are gradually being replaced by the higher derricks, in which heavier tools and long lengths of pipe can be conveniently handled.

SECTION 5.—THE TORPEDO.

In 1862 Colonel E. A. L. Roberts, then an officer in the volunteer service, conceived the idea of exploding torpedoes in oil-wells, for the purpose of increasing the production. Having applied for a patent, in the fall of 1864 he constructed six torpedoes, and early in 1865 he visited Titusville to try his first experiment. The risk of damaging the wells prevented their owners from allowing the tests to be made; but Colonel Roberts finally persuaded Captain Mills to allow him to operate on the Ladies' well, on the Watson flats, near Titusville. The explosion of two torpedoes caused this well to flow oil and paraffine. This result produced great excitement, and led to the filing of several applications for patents and as many lawsuits for infringement, which were all finally decided in favor of Roberts. The complete success of the torpedo was not established, however, until December, 1866, when Colonel Roberts exploded one in the Woodin well, on the Blood farm. This well was a "dry hole", and had never produced any oil. The first torpedo caused a production of 20 barrels a day, and the second raised it to 80 barrels. This established the reputation of the torpedo on a firm basis. (*a*)

The following notice of the decision of Judge Strong, sustaining the patent of Colonel Roberts, explains the method of using torpedoes and the opinion of the inventor regarding their action:

> The patent consists in sinking to the bottom of the well, or to that portion of it which passes through the oil-bearing rocks, a water-tight flask, containing gunpowder or other powerful explosive material, the flask being a little less in diameter than the diameter of the bore to enable it to slide down easily. This torpedo or flask is so constructed that its contents may be ignited either by caps with a weight falling on them or by fulminating powder placed so that it can be exploded by a movable wire or by electricity, or by any of the known means used for exploding shells, torpedoes, or cartridges under water. When the flask has been sunk to the desired position, the well is filled with water, if not already filled, thus making a water tamping and confining the effects of the explosion to the rock in the immediate vicinity of the flask and leaving other parts of the rock surrounding the well not materially affected. The contents of the flask are then exploded by the means above mentioned, and, as the evidence showed, with the result in most cases of increasing the flow of oil very largely. The theory of the inventor is that petroleum or oil taken from wells is, before it is removed, contained in seams or crevices, usually in the second or third stratum of sandstone or other rock abounding in the oil regions. These seams or crevices being of different dimensions and irregularly located, a well sunk through the oil-bearing rock may not touch any of them, and thus may obtain no oil, though it may pass very near the crevices; or it may in its passage downward touch only small seams or make small apertures into the neighboring crevices containing oil, in either of which cases the seams or apertures are liable to become clogged by substances in the well or oil. The torpedo breaks through these obstructions and permits the oil to reach the well.

Judge Strong, in delivering the opinion of the court, said:

> While the general idea of using torpedoes for the purpose specified is not patentable, the particular method of employing them invented by Mr. Roberts is patentable; therefore he is entitled to protection.

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a Abridged from Henry's *Early and Later History of Petroleum*, p. 257.

The material used now in the Pennsylvania oil regions is nitro-glycerine, which is manufactured for the purpose by the ton. This was first used in quantities of from 4 to 6 quarts (13½ to 20¼ pounds, equal to from 108 to 162 pounds of gunpowder). This amount was gradually increased to 20, 40, 60, 80, and even 100 quarts. When the well is ready to be "shot", word is sent to the torpedo company, and the canisters are prepared in sections of about 10 feet in length and 5 inches in diameter. These sections are made conical at the bottom, so that they will rest securely on top of each other. The nitro-glycerine is carried in cans that are placed in padded compartments in a light spring wagon, which is often driven over the roughest mountain roads with great recklessness. Arrived at the well, one of the sections of the canister is suspended by a cord that passes over a pulley and is wound upon a reel. The nitro-glycerine is poured into the canister until it is filled, and then it is lowered by the cord to the bottom of the well. Another section is filled and lowered in like manner until the proper amount is put in place. Then the cord is drawn up and a piece of cast-iron weighing about 20 pounds, and made of such a form that it will easily slide down the bore, is allowed to drop down upon the cap, which is adjusted to the last section that was lowered. At a depth of 2,000 feet no sound reaches the surface, although 80 quarts of nitro-glycerine, equal to 2,160 pounds of gunpowder, may have been exploded by the hammer. After from three to ten minutes has elapsed a gurgling sound gradually approaches the surface, and the oil, welling up in a solid column, filling the bore-hole and mounting higher and higher, falls first like a fountain, and then like a geyser, and forms a torrent of yellow fluid, accompanied by the rattle of small pieces of stone and fragments of the canister, in a shower of oil-spray 100 feet in height. In five or ten minutes it is all over; 25 or 30 barrels of oil have been thrown to the winds, and the derrick has been saturated with it, so that in a short time it becomes as black as ink and as combustible as tinder. In some instances but little oil escapes from the well, and sometimes none at all. The position of a torpedo just before explosion is shown in Fig. 31.

While not disputing that in some instances the theory of the action of torpedoes formulated by Colonel Roberts may explain such action, I am forced to the conclusion that when a torpedo is exploded in such rock as the Bradford oil-sand the crushing effect of the explosion is comparatively limited. The generation of such an enormous volume of gas in a limited area, the walls of which are already under a very high gas pressure, and which is held down by a motionless column of air of 2,000 feet (the use of water tamping has been abandoned), must be followed by an expansion into the porous rock that drives both oil and gas before it until a point of maximum tension is reached. The resistance then becomes greatest within the rock, and, reaction taking place, oil and gas are driven out of the rock and out of the well, until the expansive forces originally generated by the explosion are expended. By this reaction the pores of the rock are completely cleared of obstructions, and the pressure of the gas within the oil-rock continues to force the oil to the surface until it is no longer sufficient for that purpose.

It is found that in shallow wells of only a few hundred feet in depth, like those of West Virginia, nitro-glycerine is not as efficient as gunpowder, the violent action of the nitro-glycerine throwing the column of air or water out of a well of that depth, while gunpowder is held down.

The expense incurred by using torpedoes in wells under the Roberts patent has led to many attempts to escape it, and many parties manufacture nitro-glycerine in the oil regions and explode it in wells by stealth. Such torpedoes are called "moonlighters". Another and more safe method is to purchase two-thirds or three-fourths the amount of nitro-glycerine required of outside parties, say 40 quarts for a 60-quart charge, and then engage the torpedo company to put in the other 20 quarts and fire it off, thus avoiding the payment of the royalty on the 40 quarts. These are called "setters".

The value of torpedoes in individual cases is unquestioned; but, as a whole, their value to the oil interest is doubtful. Some very remarkable instances are on record where the yield of a well has been greatly increased by their use. The Mathew Brown well No. 6, in Fairview township, Butler county, Pennsylvania, is said to have yielded an increased production of 300 barrels the first twenty-four hours, and this from a charge of only 4 quarts. Another instance is on record where a torpedo in one well increased the flow in a second well 80 rods distant so that the yield did not run down to its former amount for six months. It is, however, the opinion of those whose long experience well qualifies them to judge that, especially in close sand, torpedoes are of very little use. By some they are no longer employed. It is manifestly a destructive method of operation that yields quick results, attended with great waste.

Section 6.—LOCATION OF WELLS.

The production of petroleum is in a general sense a speculative business. It may, however, be conducted as a regular business, involving the sagacious use of capital in such a manner as experience and judgment would dictate, with due account as to its elements of uncertainty. Conducting their affairs on such a basis, there are large corporations and individuals who command large capital and who control large tracts of proved productive territory either in fee or under leases. There are also many adventurers, who, either alone or in company with others, drill wells as they might purchase lottery tickets, losing little if they prove dry and reaping a rich reward if they prove valuable. This latter class operate almost exclusively under leases. It would be impossible to give details of the varied conditions incorporated in leases, as they are cunningly drawn in favor of the lessee or

lessor. The lease generally provides that the lessee shall drill a certain number of wells within a certain time and pay to the lessor, as a royalty, a certain proportion of the oil obtained, varying, according to circumstances, from one-tenth to one-fourth. As the reputation of territory improves, the undeveloped portion of a tract held under lease is subleased for a larger royalty or on a bonus, sometimes both. A tract originally leased on a royalty of one-eighth is subleased on a royalty of one-fourth, with perhaps a bonus of $300 an acre in addition.

The location of wells upon a given piece of land will depend upon circumstances; but I think it may be safely stated that, as a general rule, wells will be drilled along the border of a tract, rather than toward the middle. This is often to be regarded as a measure of protection, because if A does not draw as much as possible from B's territory, B is quite sure to drill a line of wells and draw from A. Wells have in many cases been located with a total disregard of all prudential considerations. In the valley of Oil creek, just above Oil City, leases of only a quarter of an acre were taken and wells drilled on them, thus insuring about twenty times as many wells as there ought to be, and reducing at the same time in a corresponding ratio the possibility of both continued yield and profit. On the Clapp farm, at the northeast end of this tract, good wells were struck, one of which, drilled in 1863, was pumping one barrel per day in 1881. Here the wells were not drilled close, but nearer the city six and even eight wells were drilled on an acre, and as a result nearly one-half of them were soon abandoned. Experience has proved that one well to five acres is as close as they should be drilled. The man who owns a lot has no safety but in getting his oil to the surface; for as long as his land remains undeveloped he is constantly exposed to the risk of having it sucked dry by the wells of his more energetic neighbor, and that is equivalent to disaster and financial ruin. If all the operators in a given district could be persuaded to enter a movement for suspending drilling, it would in the end be mutually beneficial; but in many instances lease-holders are compelled, either by the terms of their leases or by their own pecuniary embarrassments, to go ahead with development and realize as promptly as possible upon their investments.

Section 7.—THE OIL-SAND.

The character of the oil-sand has been easily studied from specimens thrown out by torpedoes. The Venango sand, extending from Tidioute to Herman station, in Butler county, is a conglomerate of small pebbles with large interstitial spaces. The depth or thickness of this sand varies from 10 or 12 to 125 feet at Triumph. When this great thickness was observed, the wells were drilled into the sand from 15 to 20 feet and pumped for a while, when it was discovered that they had not passed through the sand. On drilling through to the bottom the wells continued to produce for a long period. The Warren sand is fine-grained, bluish in color, and is inclined to be muddy, while the Bradford sand is a friable sandstone, somewhat coarse-grained, and is of a brown color.

The opinion formerly held respecting the occurrence of oil in fissures has been noted elsewhere (see page 18). It was not only held as a scientific hypothesis, but it exerted a very important practical influence on the methods employed for obtaining oil. At one time an instrument was very widely used for indicating the point at which a crevice occurred in a well, and torpedoes were introduced at such points. It cannot be denied that near the surface oil-bearing rocks do contain fissures. The Berea sandstone, where it comes to the surface at Berea, and the different members of the Venango oil-sand when they reach the surface, are fissured. The experience gained in drilling wells also shows the presence of fissures below the surface. Wells are sometimes started, and after passing through several strata reach one where, in spite of all attempts to remedy the evil, the hole will go crooked, the drill glancing from the rock on one side of the fissure, and the well, in consequence, has to be abandoned. At the same time the extent to which fissures exist in the deep beds of oil-sands is now believed to have been very much overrated. The experience gained in sinking deep wells leads rather to the conclusion that in them the drill penetrates a homogeneous solid sandstone, in the pores of which the oil is held under great pressure. Although oil is sometimes found in the joints of fractured slate or shale, the solid shale is nearly impervious, often to both oil and water, and is separated from the sandstone by a hard and wholly impervious shell or crust, which prevents the escape of the oil and gas. Sometimes, however, this crust is absent or is thin and soft, in which case oil is found in the sand-rock above; in other words, where oil is found in the second sand the crust of the third sand is not impervious.

The motion of oil laterally through the oil-sands is illustrated by numerous phenomena attending the drilling and operation of contiguous wells. It is observed that the wells and springs of water in the superficial strata fail when these strata are penetrated by deep wells. Even artesian wells sunk for water to the second sand are often drained by contiguous oil-wells sunk to the third sand in consequence of the lateral movement of the water through the second sand to the oil-well. It is asserted that the swampy section around Power's Corners, in the Mecca district, has been greatly improved by surface drainage through the numerous oil-wells that have been sunk in that neighborhood.

The capacity of a porous sandstone, or even of the coarse pebble conglomerate constituting the Venango third sand, to hold the vast quantity of oil that has poured forth from some wells has been questioned; but when we consider (1) the strong attraction existing between oils and dry surfaces, (2) the powerful capillary attraction

exerted in consequence, and (3) the enormous pressure under which the oil is held in the rock and forced out when the reservoir is perforated, there seems to be no reasonable ground for doubting the sufficiency of such a source of supply. This opinion receives further confirmation from the large content of oil proved by Dr. Hunt to exist in the Chicago limestone (see page 63).

J. F. Carll has shown by experiment that the pebble sand will absorb from one-fifteenth to one-tenth of its bulk of oil, and, further, that "the aggregate sum of the pores or interspaces of a sand-rock of this kind, as exposed in the walls of a well of 5½ inches diameter, is equivalent to the area of an open crevice one inch wide, extending from top to bottom of the gravel bed, whatever its thickness may be". He further shows that "on Oil creek there is generally from 30 to 50 feet of third sand, and also from 15 to 30 feet of stray sand, both locally producing oil. Of this total, suppose only 15 feet is good oil-bearing pebble, we shall then have a producing capacity of 15,000 barrels per acre, or 9,600,000 barrels per square mile, which is adequate to the requirements of the most exceptional cases known". (*a*)

While the Warren and Bradford sands are quite dissimilar from the Venango sand, their porosity is sufficient to hold their content of oil.

The occurrence of so-called slush oil at North Warren and at Limestone, in the Tuna valley, has been attributed to fissuring of the sandstones and shales in such a manner as to allow the oil to rise into the fissures in the shales. These cases are local and exceptional, and are therefore not to be regarded as typical of the manner in which oil occurs generally.

SECTION 8.—THE MANAGEMENT OF WELLS.

Having shown how the oil-well is carried down upon a reservoir of sufficient capacity to contain a remunerative quantity of oil, it will next be shown how the well is managed after it is drilled and torpedoed. The present methods of management are the result of an historical progressive development, which will be best understood if discussed chronologically and in connection with the figures in Plate VI and the sections, Figs. 32, 33, 34, and 35. Figs. 1, 2, and 3, Plate VI, and Figs. 32, 33, and 34 were originally drawn by H. Martyn Chance, to accompany Mr. Carll's report, and were afterward redrawn by Miss Laura Linton, with some changes, to bring them into conformity with Fig. 4, drawn by Mr. Opperman. An examination of these figures shows the well divided into four sections, viz: the surface section, the bottom of the drive-pipe section, the bottom of the casing section, and the bottom section. These different sections show the arrangements at the derrick floor, at the bottom of the drive-pipe, at the bottom of the casing or seed-bag section, and at the bottom of the well. Fig. 1, Plate VI, and Fig. 32 show a well as arranged in 1861. It is the direct descendant of the well of the Ruffner Brothers, and was then in use around Tarentum and elsewhere for salt-wells. From the well-head at the derrick floor to the bed-rock was a plank conductor or drive-pipe, which held the loose sand or gravel of the drift. From the bottom of this conductor to the bottom of the well the rocks through which the drill had cut formed the walls of the bore, which was 4 inches in diameter. Within this 4-inch hole a 2-inch pipe was inserted, with the pump-barrel screwed to its lower end. At a point estimated to be below that at which the water infiltrating the surface rocks entered the well the "seed-bag" was fastened in such a manner as to stop off this water from entering the bore of the well below. The pump-barrel being securely screwed to a length of pipe, it was lowered into the well, and piece after piece connected, until the point at which the seed-bag was to be introduced was reached; then a bag of calfskin or buckskin was securely tied to the pipe immediately below a thimble to prevent it from sliding. This bag was filled with flaxseed, and the upper end was so insecurely tied that if the tube was raised the bag would turn and empty itself. It was then lowered and the pipe added joint by joint until the required amount was put in. Beneath the thimble, at the end of the last joint, clamps were placed and securely fastened above the head-block, which rests upon the derrick floor. As the seed-bag absorbs moisture it expands and fills the 4-inch hole so completely that all of the water above the bag is held and prevented from passing below. Of course this well is drilled wet, that is, full of water, no attempt being made to stop off this water until the oil is reached and the well is prepared for pumping. If for any reason it became necessary to withdraw this tubing, the seed-bag came with it, and the water flowed into the bottom of the well.

Fig. 2, Plate VI, and Fig. 33 show the well of 1868. At this time it had become customary, after sinking the conductor or cast-iron drive-pipe to the bed-rock, to commence a 5½-inch hole, which was continued to the bottom. The position of the seed-bag was then determined, and it was securely fastened to the lower end of a section of casing-pipe 3¼ inches inside diameter. This was lowered to the proper depth. The 2-inch tubing, with the pump attached, was then lowered to the proper depth and secured at the top with the proper clamp. This well was of course drilled full of water, as the water was not stopped off until the tools were drawn out and the casing inserted. Instead of the ordinary seed-bag, a patent packer was sometimes attached to the casing in place of it. This packer was formed by pressing a sort of leather cup over an iron ring that was a little smaller than the drill-hole and was fastened to the outside of the casing. The pressure of the column of water above held the leather firmly to the drill-hole when the oil was pumped from below. Sometimes, as is represented in the figure, both the cup-packer and seed-bag were used at the same time. A casing-head was screwed on, usually with one or two outlets for gas,

a *Rep. Sec. Geo. Surv. Penna.*, III, p. 252.

and the gas that escaped inside the casing and outside the tubing could thus be utilized as fuel; at the same time the casing-head took the place of the head-block and formed a support for the tubing. In this way the casing was made a permanent fixture, effectually stopping off the water and permitting the tubing to be introduced or taken out at pleasure.

Although this method of drilling and casing wells was a great improvement over those previously employed, it still presented two very grave defects: First, the well must be drilled full of water, and, second, the hole was larger than the casing, and accidents sometimes occurred, which made it necessary to draw the casing and let the water into the well. To remedy these defects the plan was adopted that is shown in Fig. 3, Plate VI, and Fig. 34. According to this plan an 8-inch iron pipe is driven to the bed-rock. An 8-inch hole is then carried down below the surface water. The drilling-bits are then made smaller, and the hole is contracted to 5⅝ inches. A second tube, armed with a steel shoe, is then carried down inside the drive-pipe, and ground in the tapering drill-hole to a water-tight joint. This casing thus effectually cuts off the water. The 8-inch jars and drills are exchanged for 5½-inch tools, and the hole is carried down from that point of the same diameter as the interior of the casing to the bottom of the well, with only water enough introduced to sand-pump properly. The buoyancy imparted to the tools and cable by 1,000 to 1,500 feet of water is thus avoided, and the presence of oil in any of the strata penetrated is immediately manifested by escaping gas and soiled tools, and sometimes by a gush of oil that fills and overflows the well before the tools can be withdrawn.

Mr. Carll (Report III, *Second Geological Survey of Pennsylvania*, page 320) estimates that "the average cost of drilling cased wells (especially if we take into account the reduced liability to accidents from tool-sticking, etc.) is probably little, if any, greater than it would be if they were drilled wet. Quite an item in the cost of fuel is sometimes realized, for a vein of gas may be struck several hundred feet from the bottom of the well, which will fire the boiler until the work is finished".

The advantage of having a hole of the same diameter all the way down is very great when fishing operations are necessary, and also when the packers which are now used are to be inserted. These are used in preparing the well for flowing, and their use is represented in Fig. 4, Plate VI, and Fig. 35, where a cased well, with tube and packer, are indicated in full operation. These packers are of rubber, and are so constructed that the tube within them moves in a sliding joint. The lower piece of pipe enters the bottom of the mass of rubber, and the upper section, being securely fastened to the upper portion of the mass, slides in the lower section in such a manner as to press with its whole weight against the rubber and force it against the sides of the drill-hole. A well prepared for flowing as represented in Fig. 4, Plate VI, and Fig. 35, and properly connected with a tank, will operate with very little attention for months. The flow will finally run down either from the exhaustion of the supply or the clogging of the pipes with paraffine.

The clogging of pipes with paraffine occasions a great deal of trouble in the Bradford district. This is occasioned, first, by the much larger percentage of paraffine in the Bradford oil, and, second, from the condensation of the less volatile and soluble paraffines, due to the very intense cold produced by releasing the oil from the high pressure under which it exists in the rock, and consequently rapid evaporation of the more volatile portions. No attempt has been made to ascertain accurately this temperature, but many incidental facts indicate that it is very low.

After a well has ceased to flow, and in those localities where the gas pressure is not sufficient to cause the oil to flow, the well is pumped. In the method of pumping represented in Fig. 1, Plate VI, and Fig. 32 the sucker-rods were introduced immediately after the pipe and seed-bag, and, after the seed-bag had had time to swell, connection was made with the walking-beam, and the water pumped out below the seed-bag. After this water was removed and its pressure taken from the rock the gas and oil entering the well were brought to the surface. With the adoption of the first method of casing wells (Fig. 2, Plate VI, and Fig. 33), the water was removed from the space between the casing and tubing, and the oil-rock being quickly relieved of its pressure, the oil and gas rushed in to supply its place, and after the removal of the water was brought to the surface. With the drilling of dry holes the method of pumping represented in Fig. 3, Plate VI, and Fig. 34 has been adopted. In this well there is no water to pump, and the oil is brought to the surface as long as any will enter the well. Sometimes so-called gas-pumps are applied to wells that have ceased to yield oil and a partial vacuum has been created, with the result of causing the oil to flow laterally into the well through the rock.

In some localities, where the oil is valuable and the yield of the wells small, as among the heavy-oil wells of the Franklin district or in the older portions of the Oil Creek district, a method of pumping wells by sucker-rod connections has been adopted. The use of sucker-rods was no doubt adopted on account of the fact that old rods were suitable, numerous, and cheap. An engine is attached to a circular horizontal table by an elbow-joint in such a manner that it is made to perform a quarter revolution and return to its former position. To the circumference of this table from two to a dozen or fifteen connections are made, in such a manner that each connection is given an equal stroke sufficient to move a pump connection, such as is represented in Fig. 36. The pull of the engine comes on the down-stroke of the pump, and the up-stroke of the pump is balanced by the stones or other heavy material placed in a box on the arm, *a*. The rods by which these connections are made for long distances are

supported by light frames, which have a swinging motion as the rods move slowly to and fro. In the Franklin district, where the wells are shallow, the rods are made of strips of ash 2½ inches square, nailed together by wooden straps. From thirty to forty wells are thus sometimes attached to one engine. In the White Oak district of West Virginia, where the ground is too uneven to admit of wooden connections, motion is communicated to a dozen or more wells by an endless rope, usually of wire, that is supported on wheels and runs up one hill and down another and along the valleys to a convenient site for the engine. By this method wells can be profitably pumped that would otherwise have to be abandoned.

At the Katie Hough well, on Mud run, in the White Oak district, West Virginia, in the summer of 1881, the curious phenomenon was exhibited of pumping two kinds of oil from the same well. In this region there are several oil horizons, and at the point penetrated by this well the first White Oak sand produces oil of 27° specific gravity, and third White Oak sand beneath it yields oil of 45° specific gravity. The well was in 1865 put down 255 feet to the first White Oak sand, and was pumped at intervals for 15 years; it was then reamed to an 8-inch hole, and a 4½-inch hole sunk to the third sand. A tube, with a seed-bag at the bottom of the 8-inch hole, was inserted, and the heavy oil stopped off. From this tube amber oil of 45° specific gravity is pumped from the third sand. A second pump and tube was then inserted in the 8-inch hole beside the other tube and proper connections made with the walking-beam, every stroke of which pumped dark, heavy oil of 27° specific gravity from the first sand, worth $7 per barrel, and amber oil of 45° specific gravity from the third sand, worth $1 per barrel. The Shaw well, on Gales' Fork, also in the White Oak district, said to have produced $80,000 worth of oil, pumps oil of 25° specific gravity from a depth of 160 feet and an oil of the specific gravity of 40° at a point between 600 and 700 feet.

It has been the custom around Titusville and Pleasantville, when the production of a well ran very low, to introduce into it five to ten barrels of crude naphtha (benzine), and after allowing it to remain for a few days to resume pumping, an increased production being the result.

The large amount of oil that has at different times and in certain localities run to waste upon the streams has been due to unavoidable waste, to the bursting of pipes and tanks, the sinking of barges, and to oil which has escaped destruction during extensive fires. On the Allegheny river at Oil City may always be seen a thin film of oil often sufficient to produce iridescence. The quantity of oil required to produce this effect, although apparently very small, is in the aggregate quite large. Where booms are stretched across such streams the floating oil is arrested and may be pumped from the surface with water into settling tanks and collected. In this way the collection of oil has been made a profitable business, as occasion might warrant, thousands of dollars' worth having been gathered in a single season that would otherwise have gone to waste. In 1862, 4,000 barrels were dipped from the Allegheny river and was used for lubricating oil and for making lampblack.

The occurrence of oil in the drift gravels beneath the superficial clays south of Titusville has already been mentioned (see page 49). The oil here was pumped from shallow wells, dug only a few feet into the gravel. (*a*)

Section 9.—YIELD OF WELLS.

The average duration of the profitable production of an oil-well is very uniformly estimated at five years, but this period is subject to very great variations. The wells in the Colorado district, northeast of Titusville, have been pumped about twelve years, and have yielded constantly enough to more than pay expenses. In the White Oak district of West Virginia the Scott and Scioto wells, drilled in 1865, were being pumped in 1880. On the contrary, the Cole creek portion of the Bradford field had all been drilled over since 1879, and some of the wells were abandoned before June 4, 1881, while at the same date wells were flowing near Tarport, in the same field, that were drilled in 1875. As a general rule, it may be said that the nearer the wells are to each other on a given piece of property the sooner they will become unprofitable.

As an illustration: On Triumph hill eight wells were drilled in a group, two on the edge of the belt and six nearer the center. As each well was drilled it commenced to yield at the rate those previously drilled were yielding at that time. The first well was drilled in 1866, and yielded an average daily production for the first six months of 70 barrels, the second six months 41 barrels, the second year 35 barrels; it then fell off gradually until it reached 5 to 7 barrels, where it remained for two or three years; it then continued to fall, until for the three years preceding 1881 the yield was only about 1 barrel a day. The eight wells were pumped with sucker-rods by one engine. The six central wells were 9 or 10 rods apart. The sand in the center of the Triumph belt is more than 100 feet thick.

The Economites drilled two wells on their tract upon the hill east of Tidioute 300 feet apart. They started at 100 barrels a day and held it three months, then ran down to 25 barrels in two years, and during the two years following ran down to 200 barrels a week and held about that yield for two years. Two wells were drilled in

a In the summer of 1881 quite an excitement was occasioned in Titusville by the discovery of oil saturating gravel beneath the soil of gardens along the creek. Several hundred barrels were pumped and dipped from holes or pits dug over an area of several acres. It was supposed to have been the leakage from loading racks during the Pithole development.

positions *a* and *b*. They started at 125 barrels each, and in eighteen months ran down to zero. The rigs were then changed to the other side of the engines at *a′* and *b′* and the wells were redrilled. They were drilled deeper into the sand the second time, and were cased with 5⅝-inch instead of 3¼-inch casing. These second wells started off at 75 barrels a day and lasted ten years. The first wells were drilled by a man who had a hobby that 10 feet in the sand is sufficient, but the second wells were drilled through 25 or 30 feet of sand.

a *a′*
b′ *b*

The yield of some single wells has been enormous. One half of the Empire well was sold for $900, and it afterward yielded $12,000 in six days. Its owners saved 3,500 barrels a day and sold it for 10 cents a barrel. The owners of the land were unable to furnish barrels, and the royalty was put into pits dug in gravel. Well No. 4, on the Jacob and John Hemphill farm, Donegal township, Butler county, Pennsylvania, struck by McKinney Brothers in September, 1873, has produced about 110,000 barrels, and is still (1881) producing six barrels daily. The farm upon which this well is located is among the most prolific oil properties ever developed, twelve wells thereon producing over 750,000 barrels. The Divner well, No. 1, Divner farm, Butler county, Pennsylvania, has yielded about 200,000 barrels, and six years after being struck produced 13 barrels a day. The Boss well, on the J. A. Parker farm, in Armstrong county, Pennsylvania, produced about 80,000 barrels. The amount yielded by any one well in the Bradford district is much smaller, from 20,000 to 25,000 barrels being probably the highest yield.

SECTION 10.—FLOODING.

The proximity of other outlets appears to determine the duration of the flow of oil-springs or wells. The spring in the island of Zante is known to have flowed two thousand years. The Beatty well, in Wayne county, Kentucky, drilled in 1819, is still flowing, there being no other well near it. The American well yielded oil in large quantities from 1830 to 1860, but after the drilling of other wells in the neighborhood the yield fell off, and finally ceased altogether. It is therefore impossible for any producer controlling a small area to preserve his oil beneath the surface. The lateral flow of oil and water through the oil-sand has been repeatedly demonstrated. Jonathan Watson, in his experience, had known water to run into a well when the seed-bag was removed from another one-half mile distant, and in another instance red paint was put into one well and pumped out of another at about the same distance.

J. F. Carll, in Report III, *Geological Survey of Pennsylvania*, page 258, says:

> The National well No. 1 was struck in February, 1866. It was very near the northwesterly edge of a large and well-stored pool, and passed through rather an inferior oil rock as compared with that afterward found on the axis of the belt. Still it had a sufficiently free connection with the supplying reservoir to furnish a delivery of about 85 barrels per day, and it maintained its production with wonderful constancy for two years, having only declined to about 60 barrels in that time. In the summer of 1868 wells were drilled on the center of the deposit from which it had been deriving its supply. Some of these wells produced as much as 150 barrels per day. The effect on the National was immediately apparent. Its production dropped off rapidly and dwindled down to 10 barrels or less a day. * * * Harmonia well No. 1 was on the thriving northerly edge of the Pleasantville belt. The main body of oil and the best sand-rock, as afterward demonstrated, lay to the south. It started with a small yield, and at the end of a fortnight was pumping about 30 barrels per day. Gradually increasing its production, as if enlarging and cleaning out the passages leading into the supplying reservoir, it finally commenced to flow, and ran up to 125 barrels, where it remained until wells of larger flow were drilled on the center of the belt and relieved the gas pressure, when pumping had to be resumed. After this it soon fell down to an unremunerative production and was abandoned.

The early method of drilling with the well full of water prevented the escape of the oil and gas until the water was pumped out; when the rock is pierced with a hole drilled dry "the effect is similar to the sudden liberation of the safety-valve of a boiler under a full head of steam, * * * "the boiling, foaming mass is driven upward against the forces of gravity", and sometimes shoots high above the top of the derrick. The equilibrium which had been maintained for ages throughout the communicating portions of the rock is suddenly destroyed in the immediate proximity of the well by this sudden rush up the drill-hole, and material gaseous at the ordinary temperature and pressure, but fluid under the enormous pressure maintained in the oil-rock, expands and evaporates as it rushes to the surface. This action goes forward, slowly reducing the pressure upon all the communicating portions of rock, until the pressure on the oil filling the rock is only equal to that of the column filling the drill-hole. The pump is now used to lift the fluid from the drill-hole, the oil being still under the pressure of the gas ascending between the tubing and casing. The rock is still full of oil, and the pumping goes on until the pressure of the gas is scarcely sufficient to send any of it to the surface, when a gas-pump is applied at the casing-head to one of the lateral tubes and the pressure of the atmosphere removed. Still, after all this has been done, there is oil remaining in the rock. As before intimated, the oil and gas mutually dissolve each other and form a homogeneous mass, "the gas being as thoroughly incorporated with the oil as gas is with water in a bottle of soda-water." The effects of "flooding" or allowing water to enter the rock partially exhausted of its oil has been the subject of much controversy. Some producers imagine that if the rock is properly flooded the oil can be driven toward certain points and removed to advantage, but experience has proved such operations extremely hazardous.

J. F. Carll has discussed this subject in great detail, and I am greatly indebted to his report and private conversations for information on this subject. He says: (*a*)

> The first intimation of the flooding of a district is given by an increased production from the wells affected by it. Old wells improve gradually, running up from 5 to 10 or 20 or even 50 barrels. After pumping in this way for some time, the oil quickly fails, and they yield

a J. F. Carll, Report III, p. 265.

only a few barrels of salt or brackish water. * * * In some districts the movement is quite rapid, and wells are invaded and "watered out" in quick succession; in others it is so slow that large quantities of oil are obtained from those which are favorably located to receive a "benefit". Flooding a well is sometimes a very profitable way of closing up its career, inasmuch as it thus yields more in a few months than it otherwise would in years, and when the water reaches it the owner knows at once what it betokens and stops work, thus saving the time and money usually expended in fruitless efforts to reclaim a well failing through natural decline. * * * In judging of the probable effects of the introduction of water into any particular oil district several things are to be considered. (1) *The time of flooding*, whether early in the progress of development, while yet a large percentage of oil remains unexhausted, or at a later period, after the supply has suffered from long-continued depletion. (2) *The structure of the rock*, whether regular and homogeneous throughout, or composed of fine sand interbedding and connected and irregular layers of gravel, sometimes lying near the top and at others near the bottom. (3) *The shape of the area being flooded.* (4) *The position of the point at which water is admitted* in relation to the surrounding wells still pumping oil. (5) *The height* (which governs the pressure) *of the column of water* obtaining admittance. (6) *The duration of the water supply.* It will readily be seen that a *temporary flooding* of comparatively *fresh territory*, such as frequently occurred in early days along Oil creek, from the drilling of new wells without casing or the overhauling of old ones when the seed-bag was attached to the tubing in the primitive way, must necessarily be quite a different affair from one caused by a *permanent deluge* through unplugged and abandoned wells *in nearly exhausted territory*. In the former case the flood may be checked before much water has accumulated in the rock, and then the oil-flow can be reclaimed after a few days of persistent pumping; in the latter, the recovery of the oil is very uncertain, because from its long-continued extraction a greater capacity has been given to the rocks for storing water, and this being supplied from scattered and obscure sources, there is little probability that it can be shut off, although the most thorough and systematic attempts may be made to check it.

The effect of flooding upon adjacent wells is illustrated by the following incident related of the Oil Creek district: A and B owned wells 200 feet apart. A's pumped about 10 barrels a day and B's 30. B wished to pump his, but A thought his would not pay and stopped, when B soon found he could get only water. B offered A $10 per day to pump his well ten days. At the end of ten days A refused to pump, then B offered him $25 a day for twenty-five days, at the end of which time B offered A $30 a day to pump his well an indefinite period, and A consented. In the mean time the oil in B's well increased gradually until it reached 75 barrels a day, and the operation proved profitable.

This flooding of oil territory has been proved of such importance that the legislature of Pennsylvania has affixed a penalty to any neglect to "plug" abandoned wells. The plugging consists in filling them with sand. A moment's reflection will show that the owner of oil territory must have it drilled or it will be exhausted by his neighbors drilling a cordon of wells around his property. After it is drilled, the wells must flow until the pressure of gas is exhausted, or, as has been known in several cases, the casing and tubing will be thrown out of the well. A case is on record where the casing-head was anchored down with chains and the flow of oil arrested, yet the gas pressure tore away the fastenings and threw the casing out through the top of the derrick. After the oil has stopped flowing, if the well-owner does not pump, his neighbor's pumps will drain his territory, and if he "pulls out", the law compels him to fill his well with sand and ruin it forever, to prevent the public injury resulting from letting down surface water into the oil-sand. There is therefore no other alternative presented to the unfortunate possessor of oil territory but to drill and produce, whatever the price of oil may be.

CHAPTER VIII.—TRANSPORTATION AND STORAGE OF PETROLEUM.

SECTION 1.—EARLY HISTORY OF TRANSPORTATION.

But few facts have come within my notice respecting the transportation of petroleum among the primitive peoples that have used it. In Burmah it is placed in jars and transported in them about the country. The breakage of the jars and muck occasioned by the leakage is mentioned by Major Symes as one of the disagreeable adjuncts of the production in the neighborhood of Rangoon.

In this country the Seneca oil of the early days was transported in barrels or packed in bottles. Dr. Haggard, of Burkesville, Kentucky, very graphically described to me the incidents attending the trip which he took to Louisville with the first barrel of oil that was ever sent away from the American well. The odor of the oil was so pronounced that it attracted a great deal of disagreeable attention along the road, and many criticisms more emphatic than elegant were made by the passers-by and inhabitants along the route.

During the first years of the excitement oil was transported in 40 and 42 gallon barrels, made of oak and hooped with iron. Its penetrating character led those interested to coat the barrels on the inside with a stiff solution of hot glue, which forms a continuous lining, is elastic, and is not attacked by the oil. (*a*) Great difficulty has always been experienced in the transportation of crude oil in barrels, due to the fact that such oil invariably contains a trace of water, usually as much as 1 per cent., which, acting on the glue, causes the barrels to leak, and consequently a loss of oil. To remedy this difficulty, and also to decrease the labor of handling the oil, early in 1866, or possibly in 1865, tank-cars were introduced upon railroads entering the oil regions. Those first introduced consisted of an ordinary flat car, upon which were placed two wooden tanks shaped like tubs, each holding about 2,000 or 4,000 gallons to a car.

While this change in methods of transportation was taking place on the railroads, a corresponding one had grown up in river carriage. The difficulty of moving such enormous quantities of material by teams was almost insurmountable. Aside from its enormous weight and bulk, the very magnitude of the transportation, carried on as it was over roads badly and recently constructed, left them during a large portion of the year in an almost impassable condition. The mud was often limitless in extent and depth, through which waded the long trains of teams to Oil City and other points of shipment.

The following appears in Henry's *Early and Later History of Petroleum*, page 287:

> Arrangements were made with the mill-owners at the headwaters of Oil creek for the use of their surplus water at stated intervals The boats were towed up the creek by horses—not by a tow-path, but *through the stream*—to the various points of loading, and when laden they were floated off upon a pond-freshet. As many as 40,000 barrels were brought out of the creek on one of these freshets, but the average was between 15,000 and 20,000. At Oil City the oil was transferred to larger boats. At one time over 1,000 boats, 30 steamers, and about 4,000 men were engaged in this traffic. Great loss occurred from collisions and jams. During the freshet of May, 1864, a jam occurred at Oil City, which resulted in the loss of from 20,000 to 30,000 barrels of oil.

Bulk barges were also introduced on the Allegheny and Ohio rivers. These were constructed with more or less care, many of those first employed being of inadequate strength and too easily broken up in the vicissitudes of river travel. As now constructed, they are made 130 by 22 by 16 feet, in eight compartments, with water-tight bulkheads, and hold 2,200 barrels. They are still used to convey oil from the lower Allegheny to the refineries at Mingo, Wheeling, Marietta, and Parkersburg, and also to float the production from Burning Springs down the Little Kanawha to Parkersburg.

In 1871 the wooden-tank car gave place to the boiler-iron cylinder car of the present time. These are now used in transporting crude, illuminating, and lubricating oils and other petroleum products; also residuum and spent acid. They are much safer and stronger than wooden tanks, and the railroad companies require shippers to use them. The tanks are of different sizes, holding 3,856, 3,873, 4,568, and 5,000 gallons each. The heads are made of $\frac{5}{16}$-inch flange iron, the bottom of $\frac{1}{4}$-inch, and the top of $\frac{3}{16}$-inch tank iron, and they weigh about 4,500 pounds. They are about 24 feet 6 inches long and 66 inches in diameter. Those made at present hold from 4,500 to 5,000 gallons each.

Light iron tanks on wheels are used for carting the petroleum from Boyd's creek to Glasgow, Kentucky, where it reaches a railroad.

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a The barrels are first thoroughly washed, usually with a jet of steam, dried, and heated. Hot glue is then put in and distributed over the whole surface. Then by a tube a pressure of about 20 pounds per square inch is applied through the bung, and the glue is forced into the pores of the wood.—*Chem. News*, xvi, 221.

SECTION 2.—PIPE-LINES.

A wonderful revolution has taken place in the transportation of petroleum through the use of pipe-lines. The *Bradford Era* gives the following account by C. L. Wheeler:

He said in substance that the first suggestion of a pipe-line for transporting oil, so far as he knew, was made to him by General S. D. Karns at Parkersburg, West Virginia, in November, 1860. Mr. Karns said that as soon as he could raise the money he would lay a six-inch gas-pipe from Burning Springs to Parkersburg and let the oil gravitate to the Ohio river, a distance of 36 miles. For some reason this line was never laid. Some years after, Mr. Wheeler was unable to recall the exact date, a Mr. Hutchinson, inventor of the rotary pump which bears his name, conceived the idea of forcing oil through pipes, and explained his plan to John Dalzell and the narrator in the latter's office in Titusville. Subsequently Hutchinson's plans became a reality, the first pipe-line being laid from the Sherman well to the terminus of the railroad at Miller farm, a distance of about 3 miles. The inventor's idea of the hydraulic pressure of a column of that length was certainly very exalted, and he took elaborate pains to prevent the breaking of pipes. At intervals of 50 or 100 feet were air chambers like those on pumps, 10 inches in diameter, for the purpose of equalizing the pressure. These queer protuberances gave the line the appearance of a fence with ornamental posts and excited great curiosity. The weak point, however, was the jointing, which, as the pipes were of cast-iron and imperfectly finished at their ends, was very defective, and the leakage from this cause was so great that little, if any, oil ever reached the end of the line. It was a success theoretically, but a mechanical failure. Thus the expectations of easy and cheap transportation for crude oil raised by the building of the first pipe-line were ruthlessly dashed to the ground and the inventor discontinued his experiments in despair.

The first successful pipe-line was put down by Samuel Van Syckle, of Titusville, in 1865, and extended from Pithole to Miller's farm, a distance of four miles. In the fall of 1865 Henry Harley began the construction of a pipe-line from Benninghoff run to Shaffer farm, and finished it the following spring. Meantime the firm of Abbot & Harley had secured control of the Van Syckle line, and they afterward purchased enough of the Western Transportation Company's stock to control the charter and organized under it. The two lines thus consolidated were brought into successful operation under the name of the "Allegheny Transportation Company".

After the doubters were silenced by the prospect of success, the enterprise met with the most determined opposition from the army of teamsters and roustabouts, who supposed their interests were invaded by the use of pipe-lines. Mr. Harley was threatened with personal violence, his oil-tanks were burned, attempts were made to destroy the pipe-line by breaking the joints, and personal violence was offered to the men employed upon it. A few detectives, employed as teamsters, soon effected the arrest of the ringleaders, and the opposition ceased. (*a*)

At the present time the pipe-lines not only form a complete network throughout the oil regions, but there are trunk lines which extend from the oil regions to Pittsburgh, Cleveland, Buffalo, New York, and Williamsport. These trunk lines transport the oil of large areas to those cities under a high pressure, delivering thousands of barrels daily. They are laid for miles through the forest-covered hills and valleys of northern Pennsylvania and southern New York, across hills and rivers, on the surface of the ground or only slightly covered. These main lines are 6-inch pipe tested to a pressure of 2,000 pounds to the square inch and joined with couplings, into which the lengths of pipe are screwed, as are ordinary gas or water pipes.

Each well has a tank, usually of wood, holding an average of perhaps 250 barrels. With these well tanks are connected 2-inch pipes, converging toward a central point, to which there is fall enough to cause the oil to descend. Occasionally wells are so situated that the oil has to be forced by a pump over a hill.

The lines are provided with cocks and gates for opening and closing connections, and the large corporations constantly employ a corps of men in laying and taking up pipe as connections are made with new wells or broken with others. It is impossible to compute or estimate accurately the vast length of these 2-inch pipe connections. Wells are connected and left to flow for months or years, with only an occasional visit of the owner or agent. Only that proportion of the producing interest controlled by firms or corporations of strict business habits really know approximately how many miles of pipe they own, and therefore an accurate enumeration was found to be impossible; but it is safe to say that there are thousands of miles of 2-inch pipe laid for transporting oil not owned by the pipe-line companies. These lines run everywhere through the streets of towns, across fields and door-yards, under and over and beside roads, and terminate at pumping stations, at racks, or in storage-tanks. There are also racks and storage-tanks on the main lines.

The pumping stations are located at central points in the valleys. These stations consist of permanent buildings, a boiler-house and a pump-house, which contain the necessary steam-power and a steam- and oil-pump combined in one. Many of these pumps are of the Worthington pattern, and are very powerful machines, forcing the oil rapidly through great distances and in vast quantities, not only over the hills that are encountered in the course of the line, but against the friction of the pipe conveying the oil; an element in the problem of vast importance when it is remembered that the friction increases enormously as the flow of the oil is increased in rapidity. The friction on the 108 miles of 6-inch pipe between Rixford and Williamsport, Pennsylvania, is found to be equal to a column of oil 700 feet in height; that is to say, if the pipe were laid on a uniform descending grade of 700 feet between the two points and filled with oil, the friction or the adhesion between the oil and iron would prevent the oil from flowing For these reasons the pressure carried on these pumps is frequently from 1,200 to 1,500 pounds to the square inch.

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a Henry's *Early and Later History of Petroleum.*

The racks are used for loading oil from pipe-lines into tank-cars, and are so arranged that any number of cars, from one to an entire train, can be loaded at the same time. They are constructed after the following general plan: The line is brought alongside the railroad track, and perpendicular branches are brought up just as far apart as the length of a tank-car. A platform is erected of a convenient height, and each perpendicular branch-pipe is provided with a stop-cock and an elbow above it. To this elbow is attached an adjustable pipe, usually of tin, long enough to reach the man-hole of the tank-car as it stands upon the track. To load a train it is run upon the track in front of the rack, the man-hole plates are all removed, the adjustable pipes placed in position to discharge the oil into the tanks, and the oil turned on. In this way as many cars as the rack will hold, perhaps 20, holding 2,000 barrels of oil, can be loaded in an hour and a half.

The storage-tanks are situated at convenient points for construction and use in filling and emptying. Standing on the hill south of Kendall, and looking north up the Tuna valley toward Limestone, I counted about 60 of these huge storage-tanks in sight. They are placed upon the ground without any foundation, the surface being carefully leveled to receive them. The following table shows the relative capacity, dimensions, and weight of the different sizes:

Capacity.	Diameter.	Height.	Weight and value.	Sizes of iron.
Barrels.	*Feet.*	*Feet.*		
37,065.66	95.4	29	90 tons; value, $9,000;	54 plates, No. 6, sketch.
			5 cents per pound.	34 plates, No. 00, rectangular.
				68 plates, No. 0, rectangular.
				34 plates, No. 3, rectangular.
				34 plates, No. 4, rectangular.
				34 plates, No. 5, rectangular.
				200 plates, No. 6, rectangular.
				34 plates, No. 7, rectangular.
31,000.00	86.0	30	80 tons; value, $8,000;	48 plates, No. 6, sketch.
			5 cents per pound.	32 plates, No. 0, rectangular.
				32 plates, No. 1, rectangular.
				32 plates, No. 2, rectangular.
				32 plates, No. 3, rectangular.
				32 plates, No. 4, rectangular.
				32 plates, No. 5, rectangular.
				165 plates, No. 6, rectangular.
26,000.00	87.0	24$\frac{8}{12}$	66 tons; value, $7,260;	46 plates, No. 6, sketch.
			5½ cents per pound.	31 plates, No. 1, rectangular.
				31 plates, No. 2, rectangular.
				31 plates, No. 3, rectangular.
				31 plates, No. 4, rectangular.
				31 plates, No. 5, rectangular.
				169 plates, No. 6, rectangular.
22,000.00	85.0	22	53 tons; value, $5,830;	54 plates, No. 7, sketch.
			5½ cents per pound.	26 plates, No. 2, rectangular.
				26 plates, No. 3, rectangular.
				26 plates, No. 4, rectangular.
				26 plates, No. 5, rectangular.
				26 plates, No. 6, rectangular.
				156 plates, No. 7, rectangular.
16,000.00	70.0	24	45 tons; value, $5,400;	38 plates, No. 7, sketch.
			6 cents per pound.	50 plates, No. 3, rectangular.
				25 plates, No. 4, rectangular.
				25 plates, No. 5, rectangular.
				25 plates, No. 6, rectangular.
				82 plates, No. 7, rectangular.
				25 plates, No. 8, rectangular.
10,000.00	60.0	20$\frac{9}{12}$	38 tons; value, $5,320;	38 plates, No. 6, sketch.
			7 cents per pound.	40 plates, No. 4, rectangular.
				40 plates, No. 5, rectangular.
				80 plates, No. 6, rectangular.
				20 plates, No. 7, rectangular.
5,900.00	45.0	20	15 tons; value, $2,100;	20 plates, No. 8, sketch.
			7 cents per pound.	15 plates, No. 5, rectangular.
				30 plates, No. 6, rectangular.
				15 plates, No. 7, rectangular.
				44 plates, No. 8, rectangular.

The following specifications, used by the United Lines in making contracts, will give a very good idea of their construction:

UNITED PIPE-LINES.—SPECIFICATIONS FOR 35,000-BARREL TANKS.

DIMENSIONS.—Tank to be 93 feet in diameter and 30 feet high, and be composed of 7 rings.

SHEETS.—The first ring to be of No. 00 (Birmingham gauge), weighing 13.64 pounds per square foot. The second ring to be of No. 0 (Birmingham gauge), weighing 12.04 pounds per square foot. The third ring to be of No. 1 (Birmingham gauge), weighing 11.40 pounds per square foot. The fourth ring to be of No. 2 (Birmingham gauge), weighing 10.40 pounds per square foot. The fifth ring to be of No. 3 (Birmingham gauge), weighing 9.55 pounds per square foot. The sixth ring to be of No. 4 (Birmingham gauge), weighing 8.83 pounds per square foot. The seventh ring to be of No. 6 (Birmingham gauge), weighing 8.15 pounds per square foot. The bottom to be of No. 6 (Birmingham gauge), with 5 sketch plates, weighing 8.15 pounds per square foot.

ANGLE-IRON.—The bottom angle-iron to be 4 by 4 by ½. The top angle-iron to be 2 by 2 by ⅜.

RIVETS.—The bottom angle-iron and first ring to be riveted with ⅝-inch rivets; the second and third rings with ½-inch rivets driven hot, and the remaining rings with ⅜-inch rivets driven cold. The vertical seams of the first, second, third, and fourth rings to be double-riveted.

ROOF.—The roof to be conical, with a rise of at least 5 feet 6 inches to the center (1.2 inches to the foot), and to be covered with No. 20 iron, painted on both sides, and riveted to the top angle-iron. The ends of the rafters supporting the roof must not rest on the angle-iron, but upon posts placed next to the shell of the tank inside.

MAN-HOLE.—The man-hole to be of wrought-iron throughout, and 20 inches in diameter, and be placed 10 inches from the bottom of the first ring in the sheet adjoining that in which the outlet-valve is placed.

HATCHES.—There shall be two hatches in the roof, each 2½ by 3 feet, provided with suitable covers. One of the hatches shall be directly over the outlet-valve; the position of the other to be determined by the superintendent of the United Pipe-Lines.

SWING-PIPES.—There shall be two swing-pipes, one of 6¼-inch casing, for oil, and one of 1½-inch pipe, for water; each pipe to be 30 feet long, and to have 50 feet of chain fastened to it by clamps; the chain for the 6¼-inch pipe to be $\frac{5}{16}$-inch, and the chain for the 1½-inch pipe to be ¼-inch.

FLANGES.—The flange for the pipes to be of wrought-iron, and securely riveted to the tank; the flange for the 6¼-inch pipe to be at least 1¼ inches thick where the thread is cut.

VALVES AND CONNECTIONS.—The oil-valve to be a 6-inch iron body, brass-mounted, flanged gate-valve. The connections for the oil swing-pipe to consist of one 6-inch nipple (8 threads to inch), with 10 inches of thread on one end and ordinary thread on other end. One 6-inch elbow (8 threads to inch). One 6-inch elbow (8 threads to inch) on one end, and 6¼ casing-thread on other end. One 6-inch nipple 18 inches long, ordinary threads both ends (8 threads to inch). The water-valve to be a 1½-inch iron body screwed gate-valve. The water connections to be one 1½-inch nipple, with 6 inches of thread on one end and ordinary thread on the other. One 1½ nipple 6 inches long, with ordinary thread, both ends. Two 1½-inch elbows.

WINDLASS.—There shall be a windlass over one of the hatches to raise the swing-pipes.

STAIRS.—The stairs to be substantially constructed and furnished with a gate. The tank to be carefully painted with red paint, and to be completed in every part in a thorough and workmanlike manner.

The standard tank adopted by the United Pipe-Lines is the second on the list, practically holding 30,000 barrels of oil, and over 20,000,000 barrels of oil are stored in these tanks of various sizes. (*a*) The oil is subject to depreciation in value from evaporation and by leakage through the roof of the tank, by which it is converted into an emulsion locally known as "B. S.", from which the water will not separate until the emulsion is heated. These tanks are also constantly exposed to danger of fire from lightning and other accidental causes.

SECTION 3.—CONCERNING IRON-TANK FIRES.

The following discussion of the subject of tank fires is mainly abridged from an elaborate discussion of the subject by William T. Scheide, superintendent of the United Pipe-Lines:

A few of the tanks have roofs of No. 12 iron riveted and calked, but the majority have a conical, wooden roof, covered with No. 20 iron. The plate-iron roofs are more expensive, and do not remain water-tight. Iron roofs, when sunken and covered with water, are especially bad, owing to changes in the form of the shell, due to changes in the temperature, and also to filling and emptying the tank. The roof adopted is wooden, with a pitch of 1.2 inches to the foot from the center, supported on posts set inside the tank and covered with No. 20 iron, nailed to the wood and securely riveted to the shell.

Such a tank, containing 80 tons of iron, and resting upon 5,800 square feet of earth, upon which it is pressed by more than 4,000 tons of oil, would seem to be safe from lightning. The danger comes from the liability of the gas that is continually rising from the oil to be lighted from the bolt. Mr. Scheide thinks the roofs are tight enough to prevent the escape of gas, and that the firing takes place inside; but this is scarcely possible from the manner of their construction, and it is probable that the firing is due to the ignition, either within or without the tank, of an explosive mixture of gas and air. Mr. Scheide considers that the introduction of the spark can take place by following the pipes and leaping across some air space, as the tanks and pipes of the whole region are connected in a network.

These pipes are connected with the tanks in either of two ways:

1. They run up the sides and over the top of the tank, bending into the hatchway, in which case they are held to the shell of the tank by an iron band, fastened to the roof (making a connection), and extending 12 or 15 inches through the hatch into the tank. If such a pipe were struck, and the entire bolt was not conducted to the earth through and over which it passes, the residue would leap through the mixed air and gases over the oil and

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a April, 1882, 27,000,000 barrels.

fire them. To provide against this such pipes are now being bolted to a flange on the shell, and do not project through it. This arrangement is necessary for station tanks, where it is required to see the flow of oil in order to judge whether the pipe is intact.

2. As the majority of tanks are storage rather than station tanks, they are not so arranged. Oil is pumped into these through a pipe that enters through a flange at the bottom. To provide against the collection and freezing of water which settles from the oil about the outlet valve, the pipe is continued through the shell by what is called a "swing-pipe", the end of which is intended to be constantly above the surface of the oil. In this case, as in the other, the residuum of a charge might leap from the pipe to the shell and fire the tank. This swing-pipe is raised and lowered by a chain, one end of which is fastened to the pipe, and the other to a windlass placed above one of the hatches, the chain passing through the roof. Mr. Scheide suggests that such tanks be disconnected from the pipes, but remarks that the ground becomes very dry beneath them, and hence they are not in as complete connection as might at first be supposed. At the same time no such isolated tank has ever been burned. Continuing, he says:

The great majority of tanks lost by lightning have been station tanks with pipes running over the roof; but there have been tanks burned where the only pipe connection was through the shell near the bottom, the spark evidently going from the end of the swing-pipe. Well tanks of wood (usually 16 feet in diameter and 8 feet high) are quite frequently destroyed, though not more frequently in proportion to their number than iron tanks. There is always a 2-inch pipe leading over the top of these tanks and resting against the derrick over the well. This derrick, being 70 or 80 feet high, is very liable to be struck. The noteworthy point about these fires is that the pipe that leads to the tank has its other end connected with the tubing and casing in the well, and is thus afforded the most perfect earth connection conceivable. The firing in these cases is due, first, to the presence of an explosive mixture formed by the mingling of the gas from the fresh oil and the air; and, second, to the residual discharge from the end of the pipe. Either the mixture without the discharge or the discharge without the mixture would be harmless.

When a tank is fired, the roof is always blown off if there are several feet of gas space between it and the oil. There have been instances where this explosion was sufficiently intense to blow the tank to pieces. When, as has been the case this year, the tank is practically full, the explosion only starts the roof, and the fire may be, and occasionally is, extinguished by covering the rents with wet blankets, or by turning in steam. Usually, however, a tank once fairly aflame has to burn, and attention is directed exclusively to saving adjoining property. In a country as broken as this it is difficult to find sufficient ground to separate the tanks widely without going to unwarranted expense, so that from 200 to 300 feet is considered a fair interval between them. Very many are much closer than this.

A tank once fairly on fire will burn from 6 to 8 inches an hour, and will not endanger neighboring tanks (unless high wind carries the flames over them) for several hours. The danger comes usually from the "overflow"—the most extraordinary phenomenon attending an oil fire. After a period varying, in a full tank, from 5 to 12 hours, or even a little more, and when the oil has burned down about 5 feet, the tank suddenly and without any previous notice throws out in a grand flow from 8 to 12 feet (8,000 to 12,000 barrels) of burning oil. To prepare for this flood all our energies are directed until it comes. Ditches are dug and embankments thrown up between the burning tank and other property, and, if possible, the ditches are made to open into fields, where the oil can burn rapidly and without further damage.

The oil burns on the ground or on water with incredible rapidity, and will not run very far from the tank. When the flow ceases, it loses its limpidity, as its lighter parts are consumed, and when carried forward by water the flames die out in a comparatively short distance, leaving the surface covered with thick, dark-green, unconsumed oil.

At certain intervals after the first flow there will be smaller flows, and in from twenty-four to thirty-six hours the tank will be quite burned out.

The cause of these overflows is uncertain. They are probably owing, in part at least, to the heating of the subjacent oil, but not wholly.

At the Custer fire our superintendent went completely around within five minutes of the flow, and as far as he could reach the tank was quite cool to the hand.

The theories offered to account for the overflow are chiefly, first, heating the sides of the tank causes the oil to boil; second, currents of air caused by the fire itself; and, third, that, as the more volatile parts of the oil burn first, the burning surface will, after a time, become thick enough to seriously impede the free flow of gas from the oil beneath, and this obstruction becomes sufficient to permit or cause the accumulation of a quantity of gas so considerable as when it is suddenly relieved to cause the overflow. It is certain that the force excited is very great. At Custer the flow was made with such vehemence as to extinguish the flames in the tank, and for several minutes the oil left in the tank was not burning, only catching again from the fire outside.

To shorten the time during which the tank burns we "shoot" it with small cannon or rifles. Through the holes thus made a considerable quantity of oil escapes, and though the area and intensity of the fire is increased the time of danger is lessened. When spouting from holes made by rifle-balls the oil burns with an exceedingly brilliant, pure white flame, almost comparable to the electric light. Another object in shooting is to lessen the overflow by reducing the volume of unburned oil in the tank. The flames of a burning tank take a whirling motion, tending toward the center of the tank; when there is no wind the column of flame and smoke covers about two-thirds of the surface of the tank, the strong rotary movement drawing the flames from the circumference. The combustion is naturally very imperfect, and the column is chiefly dense black smoke, through which the flames, in great brilliant jets of fire, burst continually.

In a private communication of later date Mr. Scheide says:

1. We think lightning-rods are an advantage; we rodded nearly all the tanks last summer, and the result (if it was the result) indicates the advantage. Seven tanks were fired; three had no rods, and four had. But one of the four was a station tank undergoing repairs to the roof, and we think the evidence is that the discharge came from the pipe. As at least 90 per cent. of the tanks were rodded, the showing of last summer we think favorable. The rod is an inch-round iron rod 25 feet long, screwed into two iron bands (4 inches by $\frac{1}{8}$ inch), which cross each other at the apex of the roof and run radially to the circumference, where they are carefully riveted to the top angle-iron, and so to the shell. The idea is that the shell may help discharge itself as far as possible above the roof, and the spark thus kept out of the vicinity of the escaping gas. The bands are further fastened to the roofing iron (previously scraped and cleared) by screws.

2. All recent tanks have been built without swing-pipes. An arrangement devised by one of our men keeps the water out of the gate-valve, through which the tank is filled and emptied. We are now lowering the swing-pipes in all other tanks on the bottom of the tank, there to remain until fall. I think this is quite important.

3. The ground (electrical) connections of the tanks we find on test to be very much better than expected. We have had every tank in the field tested for its electrical connection with the earth and with the rods. Owing to the extreme difficulty in obtaining a perfect "ground" to test to, our results are only approximate, but a vast majority of the tanks show an average earth resistance of not exceeding 6 ohms. Their true resistance is probably much less. We were unable to get any resistance in the rod connections. We were prepared with no less resistance coil than one-hundredth of an ohm, and none of the rod connections gave as much resistance as that coil.

4. We have increased the distance between the tanks: 350 feet from shell to shell is now the minimum distance, and the average is 400 feet.

5. We are confident we can prevent the overflow if we can draw the oil out of the burning tank fast enough. A $3\frac{1}{2}$-inch cannon seems about the best instrument for the purpose, but we are experimenting with a machine that seems to promise well, which will cut a 6-inch hole without any jar to the tank, and be operated by power from a safe distance. About a dozen $3\frac{1}{2}$-inch shots will empty a tank fast enough to prevent an overflow.

6. We have given a great deal of thought to the matter of extinguishing fires. We conclude thus far that this can only be done while the roof is yet comparatively whole (it is often several hours before the roof disappears), and by steam or carbonic acid. We think steam the surest, as it can be generated more steadily. We have a large "gas-engine", with a capacity of 2,000 cubic feet per charge, but experimental tests have not encouraged us. We tried it also at an actual fire, but it was not in first-class order, having been partly broken in transit. We have built a number of 30-horse boilers and fitted them for rapid steaming with oil fuel, which we think will prove effective. We expect to have at least two of these boilers at a burning tank, with steam on, in an hour and a half at most from when it was struck, having organized very thoroughly a fire department at each of our tankage points completely supplied with every tool and machine necessary at an oil fire.

The burning of a large oil-tank at night is described as one of the grandest spectacles that can be witnessed. Considering the fact that whenever a thunder-storm passes over the oil regions it is quite probable that one or more tanks will burn, and also the seeming recklessness with which these vast reservoirs of combustible material are located in and near large towns, escape from terrible disaster seems providential. There have been several serious warnings. Red Rock station, on the Olean and Bradford narrow-gauge railroad, was burned in November, 1879. A wooden 250-barrel tank having taken fire from a lantern, the oil from this small tank ran down the valley and struck a large iron one. The flames being as high as the tank, soon set its contents on fire. The tank of oil began to burn about 7 p. m., and continued to burn quietly until 4 a. m., when it overflowed. The burning oil streamed over the sides, and, running down the main street, set the town on fire. The tank fire at Summit City was witnessed by a large company on the hill above, who were waiting for the overflow. A man fired into it with a Winchester rifle, around the circumference and at about the same height from the ground, making a fountain of fire as the jets ignited successively. Finally the oil poured over the sides all around, and a column of flame ascended at least 300 feet in height, and spread out in a horizontal sheet, like an umbrella. A gentleman beneath this sheet of flame and several hundred feet from the tank had his hat scorched.

Hair-breadth escapes from destruction are often recorded. A tank near Tarport was fired by lightning in the summer of 1880. The explosion split the cover across from side to side and set the oil on fire, the flames streaming out of the man-hole in the cover. Wet blankets were placed over the hole at first without success, but finally, by doubling them and putting wet carpets along the crack in the cover, the flames were smothered and the tank saved. On another occasion a 250-barrel wooden well tank, 16 feet in diameter and 8 feet high, nearly full of oil, and covered with loose boards, was fired by a thunderbolt. A workman near by wet his coat and thrashed out the flames. His employer gave him \$50, but told him not to risk his life another time for so small a value. These may be taken as examples of hundreds of similar incidents.

It may not be out of place here to remark that very disastrous fires have sometimes resulted from the ignition of gas at the well head when the oil-rock is perforated. One of the most disastrous fires of this kind on record occurred in 1861 on the John Buchanan farm, on the east side of Oil creek. The well was at the mouth of a small ravine formed by the waters of a spring, which, spreading out, had formed a small marsh. The well had first been drilled to the first sand and afterward put down deeper, and must have poured forth a stream of 3,000 barrels a day, as the marsh was immediately flooded with oil. The catastrophe is thus described by an eye-witness:

Just after supper on the evening of April 17, 1861, Mr. H. R. Rouse, Mr. Perry, Mr. Buel, myself, and others were in the sitting-room of Anthony's hotel, when a laborer on the fatal well hurried into the room to say that a monstrous vein of oil had been struck and barrels were wanted to preserve it. All ran to the well with the exception of myself, and I, not seeing the man who attended to the distribution of barrels, started in the opposite direction for teams to haul the necessary packages. I had completed my errand, and was on a full run for the well, with less than 20 rods to make, when an explosion occurred which nearly took me from my feet. On the instant an acre of ground, with two wells and their tankage, a barn, and a large number of barrels of oil were in flames, and from the circumference of this circle of fire could be seen the unfortunate lookers-on of a moment before rushing out enveloped in a sheet of flame that extended far above their heads, and which was fed by the oil thrown upon their clothing by the explosion. * * * The well burned three days before it could be extinguished, which was finally done by smothering it with manure and earth. Its appearance while burning was grand. From the driving-pipe, 6 inches in diameter, to the height of 60 or 70 feet arose a solid column of oil and gas, burning brilliantly. Above this hovered an immense cloud of black smoke, which would seize sections of the ascending flames, and rolling over and over, first exposing to the view cloud and then flame, would rise a hundred feet higher before the flame would fade out. From the main column below millions of individual drops of oil would shoot off at an angle, and then turning the arc of a circle drop burning to the ground, presenting all the hues of the rainbow, making a scene like enchantment, the whole accompanied by a roar hardly inferior to that made by Niagara Falls. (a)

Mr. Henry R. Rouse, one of the owners of this well, was among those fatally burned. On other occasions a fountain of oil projected high into the air has burned continually for weeks before the flames could be smothered.

a Henry's *Early and Later History of Petroleum*, p. 338.

Oil in transit in tank-cars has also occasioned terrific fires. Travel stopped ten hours on the Central railroad of New Jersey in 1876 by the burning of oil cars. The following telegraphic dispatch illustrates the extent of such disasters:

PORT JERVIS, NEW YORK, *October* 5—3 p. m.—The fire broke out at 1.40 p. m., and is burning fiercely. There are fifteen cars in the train, which are exploding one after the other. No one dares approach within a hundred feet of the train. Rails will have to be laid for a distance of nineteen car-lengths before trains can pass.

The following is from *Stowell's Petroleum Recorder*, June, 1880:

The greatest oil fire on record occurred in Titusville, Pennsylvania, on the 11th of June, 1880. It continued three days, and was caused by lightning striking a large iron tank filled with crude oil on a hill south of the city, from which the burning fluid rolled down the declivity, consuming refineries, tanks of crude oil, tanks of benzine, tanks of distillate, houses, stables, and bridges; burning some 200,000 barrels of oil, 8 or 10 iron tanks, 2 refineries, 2 bridges, 20 or 30 dwellings, and everything that could be burned in its resistless course to the creek below. The estimated loss was $500,000.

The United Pipe-Lines mutually insure their patrons against losses by fire and other accidents. The following notice will illustrate the manner in which the assessments are made after any accident which involves a loss of oil:

GENERAL OFFICE UNITED PIPE-LINES,
Oil City, Pennsylvania, August 30, 1880.

The patrons of the United Pipe-Lines are hereby notified that all credit balances upon the books of the United Pipe-Lines at the close of business August 28, and all outstanding acceptances issued on and before that date, are subject to an assessment of twenty-one one-hundredths ($\frac{21}{100}$) of 1 per cent. in pipeage paid oil, on account of loss by fire, on August 28, 1880, of tank United register No. 738, located at Babcock, on the Erie railroad, McKean county, Pennsylvania.

WILLIAM T. SCHEIDE, *General Manager.*

SECTION 4.—CONCERNING THE STORAGE OF OIL AND ACCUMULATED STOCK.

The legislature of Pennsylvania has required the incorporated pipe-lines whose certificates are negotiable paper to publish a monthly statement of their condition. The following abstract of a report made in conformity to the requirements of that law affords a sufficient illustration of its operation:

STATEMENT OF THE TIDE-WATER PIPE COMPANY, LIMITED.

(Made in compliance with the act of assembly approved May 22, 1878.)

First. Quantity of crude petroleum which was in the actual and immediate custody of said company at the beginning of the month of March, 1881, 1,594,900.68 barrels.

Quantity of crude petroleum which was in the actual and immediate custody of said company at the close of the month of March, 1881, showing where the same was located or held, describing in detail the location and designation of each tank or place of deposit, and the name of its owner, viz:

Designation of tank.			Name of owner.	Location.	Barrels and hundredths of barrels of 42 gallons each.
Wood or iron.	Marked.	Numbered.			
Iron	Tide-Water Pipe Company, limited	2	Tide-Water Pipe Company, limited	Otto township, McKean county, Pennsylvania	25,238.86
Iron	do	12	Knapp's Creek Oil Company, limited	do	23,803.26
Iron	do	15	Hoyt & Emerson *et al*	do	25,608.53
*	* *	(*)	* *	* * *	1,459,695.10
Wood		1	do	Gibson's Point, Philadelphia, Pennsylvania	438.29
Iron	Tide-Water Pipe Company, limited	63	do	do	3,119.68
Iron	do	66	do	Thurlow, Delaware county, Pennsylvania	29,884.66
Iron	do	67	do	do	28,114.48
				Total fluid in tanks	1,595,902.86
				Less sediment and surplus	33,903.97
				Net amount of oil in tanks	1,561,998.89
Contained in 138 tank-cars in transit.	Capacity, 106.66 barrels each			Between Williamsport, Pennsylvania, and Bayonne, New Jersey.	14,719.08
Contained in 28 tank-cars in transit.	Capacity, 106.66 barrels each			Between Williamsport and Philadelphia, Pennsylvania.	2,986.48
Contained in 41 tank-cars in transit.	Capacity, 106.66 barrels each			Between Philadelphia and Thurlow, Pennsylvania.	4,373.06

Miles of pipe.	Inside diameter.	Capacity per mile.	Total capacity.	Estimated contents.
	Inches.	*Barrels.*	*Barrels.*	*Barrels.*
93.95	2.067	21.914	2,058.82	1,029.41
27.68	3.067	48.247	1,335.48	1,335.48
14.93	4.026	83.137	1,241.24	1,241.24
108.24	6.065	188.672	20,421.86	18,379.67
2.04	7.982	326.790	666.65	666.65
0.62	12.025	741.677	459.84	459.84

Total	23,112.29
Total barrels	1,607,189.80

Second. Quantity of crude petroleum which was received by said company during the month of March, 1881, 159,874.51 barrels.

Third. Quantity of crude petroleum which was delivered by said company during the month of March, 1881, 145,699.68 barrels.

Fourth. Quantity of crude petroleum for the delivery or custody of which said company was liable to other corporations, companies, associations, or persons at the close of the month of March, 1881, 1,607,189.80 barrels.

Fifth. Amount of such liability which was represented by outstanding certificates, accepted orders, or other vouchers, 1,325,400 barrels.

Amount of such liability which was represented by credit balances, 281,789.80 barrels.

Sixth. All the provisions of the act above referred to have been faithfully observed and obeyed during the said month of March, 1881.

No refined petroleum was in the custody of said company during the month of March, 1881, nor was said company liable during the month for the delivery of any refined petroleum.

D. B. STEWART.
B. F. WARREN.

COMMONWEALTH OF PENNSYLVANIA,
County of Crawford:

Before me, a notary public within and for said county, duly authorized by law to administer oaths, personally came D. B. Stewart, having charge of the books and accounts of the Tide-Water Pipe Company, limited, and B. F. Warren, having charge of the pipes and tanks of said company, who, being each duly sworn, depose and say that they are familiar and acquainted with the business and condition of said company and with the facts set forth in the above report, and that the statements made therein are true to the best of their knowledge, information, and belief.

Subscribed and sworn before me this 9th day of April, 1881.

JOHN O'NEILL, *Notary Public.*

At the close of the census year the accumulation of gross stocks in the tanks of the United lines, according to their published statement, was 10,306,078.79 barrels, and of this 454,193.73 barrels was estimated to be "sediment and surplus". At the same time the tide-water pipe-line report gross stocks in tanks at 978,183.30 barrels and 18,657 barrels "water and sediment". Concerning this surplus Mr. Scheide writes:

Our "surplus" is the amount in which our gross stocks exceed our liabilities of all kinds, and we estimate that it is large enough to enable us to deliver all the oil we owe with a safe limit. We keep it at from 3½ to 4 per cent. of our liabilities by monthly purchases. Every year we make a careful inspection of the contents of our tanks. By an instrument called a "thief" we can take samples from any depth in the tank through four gauge-hatches in the roof. These samples, when not clearly merchantable oil, are carefully heated in white-glass bottles having leveled bottoms. The heat completely separates the oil from the water, dirt, and paraffine, which last settles in time into a compact mass at the bottom. There being a clear line of separation, the percentage of oil in the sample is thus readily obtained. In our calculations of the value of our "B. S." we usually make a further reduction of from 10 to 50 per cent. to cover the expense of the separation. This can only be determined by experts. In addition to the annual inspection, there are two experts engaged every day in inspecting the tanks to see whether the water or "B. S." is accumulating, which is about the only way we have of finding small leaks in the roof. It is impossible to give any idea as to how fast "B. S." is formed. The quantity formed differs in the widest manner in adjacent tanks; with rain carefully excluded, its formation, after that naturally in the oil (there is a small percentage in almost all fresh oil) had settled, would be commercially insignificant. We have enormously reduced its formation by the careful attention we have for two years been giving our tank roofs. I think that 3 per cent. is an ample surplus on a stock exceeding 20,000,000 barrels, but the percentage would have to increase rapidly if the stock was materially reduced.

The total net stock in tanks June 1, 1880, was estimated to be 11,737,890 barrels, exclusive of the Franklin pipe-line, the Smith's Ferry Transportation Company, and the West Virginia Transportation Company, all of which handle oils that do not enter the general trade, and also exclusive of the oil in well tanks throughout the Pennsylvania region. The condition in which much of this vast quantity of oil actually is can only be determined when it is drawn out of the tanks, in which some of it has been stored for years, although the larger portion of it is not allowed to remain more than two or three years without being changed. Oil soon loses the more volatile portion by evaporation, and increases in density, becoming more difficult to refine, but in other respects remains unchanged in quality. "Formerly, when stills were run slowly, and the product desired was the greatest possible percentage of illuminating oil, age was an advantage, and for many years oil of 45° gravity and under was worth one-half cent a gallon more than lighter oil; indeed, by a rule of the New York produce exchange, no oil of over 47° was merchantable except at a cut. For several years the greatly increased value of the other products of distillation has completely changed this rule." The oils in the tanks are therefore kept as new as possible.

William T. Scheide, in a private communication, says:

Oil is steamed in winter to free it from snow and ice and in cases to make it more limpid, as oil from very "gassy" territory thickens rapidly in the cold and will not run through any long line without warming. Orders are that the oil shall not be heated above 80° or 90° F., and not run warmer than 65° to 70°; but these figures are, no doubt, frequently exceeded. There is a great loss in this steaming, both to the producer because of the evaporation and to the pipe-line because of the condensed steam held in the oil. Many merely blow steam in and do not usually heat with a coil, as they should. The United Lines deduct from the amount shown by the gauge one-tenth of 1 per cent. for each degree F. that the temperature of the oil run stands above the temperature of the oil in three iron tanks at either Tarport or Oil City (according as the run is made in the upper or lower country), which are held untouched for this purpose.

B. F. Warren, of the Tide-Water Pipe Company, has made a very careful study of the effects of steaming oil, and has reached some conclusions, which are embraced in the following communication:

Inclosed find a tabulated statement of some results which I obtained in experiments in the field with steamed oil. You will notice some wide variations and apparent discordance in the results. These are mainly due to the imperfections of the tanks. You will understand that the tanks are of wood, and the action of steam is apt to make them leak, so much so that we almost invariably are obliged to "drive hoops" on tanks at the end of the steaming season. Some careful laboratory work gave me a rate of increase for each degree of heat from 40° to 80° F. at 0.000465; below 40° the rate of increase or decrease was noticeably less, although not measurably so, with the facilities which I was possessed; above 80° the rate seems to increase rapidly.

COMPARATIVE RESULTS OF STEAMING OIL, FROM TESTS MADE IN THE BRADFORD OIL-FIELD.

Number of tank.	Owner.	District.	COLD.				STEAMED.								
			Temperature.	Gauge.			Temperature.	Gauge.			Increase of temperature.	Increase of volume in barrels.	Water and B. S.	Net increase.	Rate of increase for each degree.
			Deg. F.	Ft.	In.	Barrels.	Deg. F.	Ft.	In.	Barrels.	Deg. F.				Deg. F.
292	....	Bradford........	30.7	6	11⅝	235.52	77.0	7	4⅝	248.91	46.3	13.39	9.62	1.64	0.00020
811	W. Chambers..........	West Branch ...	37.8	6	11⅝	229.59	103.8	7	1	234.41	66.0	4.82	9.41	4.82	0.00036
30	——— Robbins.........	Dallas	26.0	6	11	223.58	86.0	7	4	235.91	60.0	12.33	1.25	10.08	0.00072
48	Ford & Weaver........	....do	31.0	5	6	181.58	80.0	5	9½	190.66	49.0	9.08	....	....	....
380	Knapps Creek Comp'y.	Rixford.........	28.0	7	2	236.92	85.0	7	6	246.90	57.0	9.98	9.26	0.72	0.00006
459	Larmouth.............	Dallas	26.0	7	1	229.72	100.0	7	7	245.70	74.0	15.98	2.50	12.52	0.00074
677	D. A. Wray............	Coleville........	40.0	14	6¼	761.36	63.0	14	10¾	778.13	23.0	16.77	19.51	....	....
703	Evans & Houtz........	....do	33.0	4	10½	169.91	94.0	5	1	176.89	61.0	6.98	....	....	....
740	Evans & Thompson....	Bordell	34.0	10	7	549.59	84.0	11	0½	571.38	50.0	21.79	5.94	15.85	0.00058
838	......do	....do	30.0	10	8½	537.34	90.0	11	4	565.10	60.0	27.76	11.95	18.71	0.00055
969	Union Oil Company....	... do	32.0	6	7⅜	214.80	82.0	6	11½	224.11	50.0	9.31	5.58	3.73	0.00035
970	......do	....do	40.0	6	9¼	216.03	85.0	7	0¼	223.22	45.0	7.19	....	....	0.00074
1025	......do	....do	32.0	5	11	199.76	85.0	6	3	210.22	53.0	10.46	4.57	5.99	0.00056
1027	......do	....do	40.0	6	8¾	209.97	90.0	7	0¼	218.29	50.0	8.32	2.38	5.94	0.00060
1059	......do	....do	40.0	6	9¾	243.62	85.0	7	0	250.32	45.0	6.70	....	....	0.00061
1060	......do	....do	28.0	7	4¼	263.12	85.0	7	9	277.71	57.0	14.59	2.87	11.72	0.00078
1064	......do	....do	30.0	7	0½	252.66	100.0	7	7	271.96	70.0	19.30	0.75	18.55	0.00106
1065	......do	....do	34.0	7	1½	255.77	88.0	7	3¾	262.50	54.0	6.73	4.48	2.25	0.00020
1074	......do	....do	34.0	7	3½	259.88	80.0	7	6¾	269.44	46.0	9.56	0.68	8.88	0.00074
1075	......do	....do	40.0	6	3	222.75	85.0	6	6	231.66	45.0	8.91	1.49	7.42	0.00074
1076	......do	....do	42.0	6	3	223.23	90.0	6	6¾	234.37	48.0	11.14	3.71	7.43	0.00064
1076	......do	....do	40.0	7	3½	260.36	92.0	7	7¼	271.27	52.0	10.91	0.70	10.21	0.00075
	Average	....	....	.....	.....	....	....	.....	.....	....	....	....	....	....	0.00058

Number of tank.	Owner.	District.	COOLING.							Gauge when run.		Remarks.
			Temperature.	Gauge.			Temperature.	Decrease of volume in barrels.	Rate of decrease for each degree.			
			Deg. F.	Ft.	In.	Barrels.	Deg. F.		Deg. F.	Ft.	In.	
292	....	Bradford........	43.0	7	2	241.88	34.0	7.03	0.00085	7	2	
811	W. Chambers..........	West Branch ...	90.7	6	11 15/16	230.08	13.0	4.33	0.00150	7	1	The small increase and large decrease of these tanks would seem to indicate a leak in tank.
30	——— Robbins.........	Dallas	68.0	6	11½	224.83	18.0	11.08	0.00273	6	11	
48	Ford & Weaver........	....do	66.0	5	8½	188.07	14.0	2.59	0.00096	5	8½	Water not drawn.
380	Knapps Creek Comp'y.	Rixford.........	70.0	7	1	234.41	12.5	2.51	0.00085	6	9¼	Contained an excessive amount of water.
459	Larmouth.............	Dallas	68.0	7	5	239.72	32.0	5.98	0.00078	7	4	
677	D. A. Wray............	Coleville........	60.0	14	10¼	776.28	3.0	1.85	0.00081	14	5	
703	Evans & Houtz........	....do	70.0	5	0	174.10	24.0	2.79	0.00066	5	0	Water not drawn.
740	Evans & Thompson....	Bordell	70.0	10	11	565.45	14.0	5.93	0.00075	10	9½	
838	......do	....do	71.0	11	2	557.84	19.0	7.26	0.00070	10	11	
969	Union Oil Company....	... do	62.0	6	10½	221.63	20.0	2.48	0.00056	6	8½	
970	......do	....do	65.0	6	11½	221.43	20.0	1.79	0.00042	6	11½	Water not drawn.
1025	......do	....do	67.0	6	2	207.61	18.0	2.61	0.00070	6	0¼	
1027	......do	....do	68.0	6	11	215.32	22.0	2.97	0.00060	6	10	
1059	..... do	....do	60.0	6	11¼	248.09	25.0	2.23	0.00040	6	11¼	Water not drawn.
1060	......do	....do	58.0	7	7¼	272.69	27.0	5.02	0.00067	7	6¼	
1064	......do	....do	72.0	7	5½	267.61	28.0	4.35	0.00060	7	5½	Water not drawn.
1065	......do	....do	54.0	7	0½	251.28	34.0	11.22	0.00130	6	10½	Tank probably leaked some.
1074	......do	....do	60.0	7	5¾	266.50	20.0	2.94	0.00060	7	5¾	Water not drawn.
1075	......do	....do	64.0	6	4½	227.21	21.0	4.45	0.00090	6	4	
1076	......do	....do	66.0	6	5½	230.60	24.0	3.71	0.00066	6	4¼	
1076	......do	....do	78.0	7	6¼	268.48	14.0	2.79	0.00060	7	6	
	Average	....	......	.....	.....	....	....	....	0.00085	......	.....	

NOTE.—The quality of the oil does not appear to be affected by steaming. Except in two cases the gravity was not sensibly changed; in one case the gravity was increased from 43 to 40°, in the other decreased from 40 to 42.5° Baumé. The variation between the apparent increase and decrease is due to the fact that all oil at temperatures below 40° F. contains varying proportions of water when it comes from the wells, and will not settle until the temperature is raised. There is also a portion of the oil destroyed by the action of steam, forming so-called B. S.

The problems in hydraulics presented in the construction and management of pipe-lines, particularly those lines that may be denominated trunk lines out of the oil regions, are many and intricate, and required great courage on the part of those who projected the first line to meet and surmount them. These men had only the quite different problems and experience met in laying pipes for water to guide them. These problems dealt with a homogeneous

fluid, flowing through pipes, laid permanently on curves of large diameter, flowing slowly under a low pressure and delivered slowly. This water pressure seldom exceeded from 40 to 50 pounds per square inch. The pipe-line problems dealt with a fluid varying in density with the temperature, flowing easily in summer and with difficulty in winter through pipes of small diameter, laid hurriedly and frequently changed, often on sharp curves or at right angles, for rapid movement and delivery, and at high pressures to compensate in part for the friction due to long distances and rapid transmission and small diameter of pipe, as well as at much greater elevations than are found in water-mains. The pipes used in pipe-lines are all tested to 2,000 pounds per square inch. The small sizes, 2-inch, 3-inch, and 4-inch, are worked under a pressure of 1,600 pounds, and the 5-inch and 6-inch at 1,000 pounds per square inch.

Elaborate governmental and other experiments have been made in Europe with reference to the storage and transportation of petroleum and its products. These have been mainly directed toward storing the oil under water, either in barrels or submerged cisterns, or toward a method of solidifying the petroleum or its products. The most successful plan for storing oil in submerged cisterns appears to be that of Ckiandi, an engineer of Marseilles, and consists of a cistern of masonry, provided with an inverted bell resembling a gasometer, beneath which the oil is held over water. (*a*) At Saint Ouen, near Paris, floating reservoirs of iron of an approximate capacity of 100 barrels have been used for a long time. Fourteen of these reservoirs were constructed in 1877, with a total capacity of 900,000 gallons. They were made of $\frac{3}{16}$- to $\frac{1}{4}$-inch iron, and weighed in the aggregate 151 tons. (*b*)

The so-called process for solidifying petroleum has been very widely noticed. It consists in producing with the petroleum a little water and saponaria root, an emulsion which is considered harmless for transportation. To recover the oil a little pure carbolic acid or strong acetic acid is added, and the constituents again separate. As *saponaria* is a product of the Levant and a drug of considerable value, this and other similar methods are rendered too expensive if their inconvenience was not an insurmountable obstacle to their employment. Such experiments furnish curious but impracticable results.

Concerning the proposed transportation of oil in bulk, the following from the *Oil and Drug News* presents the latest aspect of the question:

> The report from Philadelphia that the steamer Vaderland, of the Red Star line, had been purchased by a number of capitalists for the purpose of transporting petroleum in bulk has attracted considerable attention at the various commercial exchanges. The transportation of oil in bulk is not entirely an experiment. A number of sailing vessels have already been fitted up for this purpose, and have, to a certain extent, demonstrated the practicability of the idea. This is the first time, however, that a steamer has been constructed solely with the view of transporting safely large quantities of petroleum in bulk. The advantages of the system are, first, that it enables a steamer to carry a much greater amount of petroleum than it could if stored in barrels; and, second, it saves the expense of the barrels, each one of which costs exactly as much as the refined oil it contains. Not only this, but it also saves the expense of returning the barrels from Europe for use again.
>
> Inquiry among petroleum men and shipping merchants in this city elicited the general opinion that the idea is not considered practicable. Said one well-known oil inspector: "It is my opinion that the system will not work. It has been tried three times on sailing vessels during the past eight years, and each time the vessel was lost. The captain of one of them, who was saved from the wreck of his vessel, said to me that the difficulty was that the oil seemed to move quicker than water, and in rough weather, when the vessel was pitched forward, the oil would rush down and force the vessel into the waves much the same as improperly stored bulk grain does sometimes in stormy weather. It may be that by stowing the oil in small compartments it could be transported with safety, but I doubt it. Besides, what is the advantage of the system any way? The vessel must return in ballast, and it might as well bring back barrels, which under the present system are used over and over again, but under the proposed method would not be needed in the export trade."
>
> Messrs. Slocovich & Co., the well-known shipping merchants, state that about eight years ago one of their vessels was fitted up with tanks for transporting oil in bulk. She proceeded on her journey and was never heard from. Her loss was undoubtedly due to her mode of carrying petroleum. Another shipping merchant stated that he believed the idea to be impracticable. It might be possible to make the tanks strong enough to prevent the escape of the vapor of the oil, but all previous experiments had proven failures, and there was no reason to suppose that this would succeed. An experiment to transport molasses in bulk has been tried within two or three years, and two vessels were fitted up for the purpose to run between Cuba and Boston. The experiment, however, proved a failure, and the project had been abandoned. The Vaderland is an iron screw steamship, built at Yarrow-on-Tyne, in England, in 1872, and was extensively repaired last year. Her capacity for cargo is 2,001 tons. She is owned in Antwerp.
>
> The "oil in bulk" movement does not meet with favor among practical exporters. They say that it cannot be carried out successfully. It would seem, however, that oil might be transported in vessels in that way as well as grain, and the day will no doubt come when a means to that end will be devised.

Section 5.—STATISTICS OF THE TRANSPORTATION OF OIL DURING THE CENSUS YEAR.

Statistics have been received from the following-named pipe-lines that were engaged in business during the whole of the census year:

United Pipe Lines.
Tide-Water Pipe Company, limited.
West Virginia Transportation Company.
Franklin Pipe Line.
Smith's Ferry Transportation Company.
Octave Oil Company Pipe Line.

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a *Engineering*, xv, 279.

b *London Inst. Civ. Engineers*, l, 200. *Nouv. Ann. de la Construction* (3), ii, 83.

Fox Farm Pipe Line.
Shæffer and Charley Runs Pipe Line.
Tidioute and Titusville Pipe Line.
T. C. Joy.

There were also four other pipe-line companies doing business at the beginning of the census year that went out of business during that year, of which such statistics are incorporated with those of the other lines as can be obtained from their printed statements. These lines are:

Pennsylvania Transportation Company.
Church Run Pipe Line.
Cherry Tree Run Pipe Line.
Emlenton Pipe Line.

Beside these lines, there were a number of small private lines, particularly in the lower country, of which no reports are published, and from which it was impossible to obtain statistics, except at an unwarranted expenditure of time and labor, if, indeed, they could be obtained at all. These statistics, if obtained, would not materially change the significance of the figures here presented.

The total amount of capital invested in the ten pipe-lines above mentioned was $6,347,930, and the total amount paid in wages during the year was $769,641. The greatest number of hands employed by them during the census year was 1,381; the average number 1,107, of whom 1,098 were males above sixteen years, 6 were females above fifteen years, and 3 were children.

The hours of labor constituting a day were in general ten, but some of the operations of pipe-lines require constant oversight, and therefore in some instances the labor is performed by men who work in "tours" of twelve hours each, extending from twelve o'clock at midday to twelve o'clock at night, and from twelve o'clock at night to twelve o'clock at midday.

The ten lines in operation at the end of the year were in operation throughout the year.

The average wages of skilled workmen varied from $1.75 to $3.33 per day and from $70 to $75 per month; that of ordinary laborers from $1.25 to $2.50 per day.

A marked difference in the rate of wages is found to exist in different sections of the oil-producing country. This difference is no doubt determined to some extent by the magnitude of the operations of the lines and the responsibility attaching to the labor performed.

The total amount expended for fuel by these ten lines (not including the value of a vast quantity of natural gas, of which no account was taken) was $127,058. The total amount received for transporting (piping) oil was $1,381,328. The total number of boilers used was 216, having an estimated horse-power of 4,301; of pumps on main lines, with a diameter of cylinder varying from 3 to 34½ inches, and a length of stroke varying from 4 to 36 inches, 383; of pumps used in collecting oil (for the most part small portable pumps), 511; of iron tanks, 646, with a total capacity of 12,958,385 barrels; and of wooden tanks, 383, with a total capacity of 239,587 barrels.

The total miles of pipe controlled by pipe-lines was:

	Miles.
12-inch pipe, several hundred feet.	
6-inch pipe	121.66
5-inch pipe	7.75
4-inch pipe	123.73
3-inch pipe	289.65
2½-inch pipe	16.00
2-inch pipe	1,716.23
1½-inch pipe	2.78
1-inch pipe	9.05
Total miles of pipe	2,286.85

	Barrels.
The stock of oil on hand in tanks and pipes June 1, 1879, was	6,753,909.02
In the other four lines	28,795.33
Total	6,782,704.35
The amount run into these lines during the census year was	22,516,676.27
Into the other four lines	370,110.96
Total	22,886,787.23
The stock on hand in tanks and pipes May 31, 1880, was	11,239,555.73
In the other four lines	18,022.31
	11,257,578.04
The amount transported through the pipes during the year was	18,411,913.54

There were 36 racks belonging to these lines, at which 561 tank-cars could be loaded at one time, and 287 tanks on cars, having an aggregate capacity of 30,230 barrels.

CHAPTER IX.—PETROLEUM IN COMMERCE.

SECTION 1.—COMMERCIAL VARIETIES.

Few persons are aware that there is more than one variety of petroleum, and those who know that some petroleums are relatively heavy and are used for lubrication suppose the light oils to be of one definite quality. The petroleum of Oil creek in early days was known to be inferior for many purposes to the amber oil of the lower Allegheny. During the first ten years of its development the oil produced in Pennsylvania was practically one thing, and the light oils of West Virginia and southern Ohio were not particularly different. The wonderful expansion of the lower Allegheny field, which commenced in 1872, was accompanied by a corresponding decline in the Oil Creek district in such a manner that the bulk of the production was shifted from the green oil of Oil creek to the amber oil of Armstrong and Butler counties. It was soon discovered that this amber oil was of superior quality for refining purposes, so superior, in fact, that refiners would secure it if possible. When, in 1876, the production of the Bradford district assumed importance, it was discovered that it was the least valuable variety of petroleum for refining yet discovered in large quantities. The price of oil from these different sections has, however, been uniformly the same, irrespective of quality, and has been the ruling price in commerce.

At the same time the heavy oil of Mecca has been sold at from ten to twenty times the price obtained for the light oils of other districts. Those of Belden, Ohio, and West Virginia have been graded according to their density and the effects of cold upon them. The Smith's Ferry oils have been sold for about three times the value of the light oils, and the Franklin oil at five to six times the value of the same.

The West Virginia Transportation Company divides the oil which it handles, which embraces the larger portion of the production of West Virginia and a part of that of Washington county, Ohio, into seven grades, as follows:

A, 37.1° Baumé and lighter.
B, 33° to 37° Baumé, inclusive.
C, 31.6° to 32.9° Baumé, inclusive.
D, 30.6° to 31.5° Baumé, inclusive.
E, 29.6° to 30.5° Baumé, inclusive.
F, 28.6° to 29.5° Baumé, inclusive.
G, 28.5° and heavier.

Grades from C to G, inclusive, are also separated into "cold-test" and "weak" oils, zero being the standard.

In order to establish these grades an inspector is appointed, who stands between the producers and the transportation company or the purchasers. These oils are for the most part quite dense, and their value varies greatly with the density; the more dense they are the greater the amount of water which they will hold mechanically and the more difficult it is to separate it. The inspector has an office near the central portion of Volcano, and has there instruments for accurately estimating the specific gravity, the water or other sediment, and the temperature at which it will thicken above zero, Fahrenheit, in accordance with the following directions:

> In receiving and making delivery of oils shipped by the company, the water and sediment contained therein shall be determined by mixing an average sample with an equal quantity of benzine, and subject the mixture to 120° F., in a graduated glass vessel, for not less than 6 hours; after which the mixture cools and settles, not less than two hours for light grade, three hours for A grade, four hours for B grade, six hours for C grade, eight hours for D grade, and eighteen hours for heavier grades.

The inspector certifies to the amount of water in the oil upon the back of the receipt issued by the company. This company has also incurred the expense of a very elaborate research upon the coefficient of dilation of oils of different density for each degree of temperature from 0° to 130° F., with the unit at 60°. The compilation was made by Mr. Julius Schubert, of Parkersburg, West Virginia.

The tables, through the kind permission of M. C. C. Church, esq., secretary of the company, are given on pages 111–115. In relation to them Mr. Schubert writes:

> In regard to the expansion table you mentioned in your letter, please let me state that the experiments were made according to a method given by Gay-Lussac, and the formula used for the calculations was also given by the same author.

$$\frac{1+kt}{1+at}=\frac{P-p}{P}$$

Where—

P = weight of the fluid before heating it.
p = weight of the fluid after heating and after the apparent expansion has been removed.
t = change of temperature.
k = coefficient of expansion of the glass = 0.000026.
a = coefficient of expansion of the fluid.

The glass used was a liter-bottle with a narrow neck. Instead of finding p, the apparent expansion P—p was directly ascertained by weighing the amount of oil taken out of the bottle. A small pipette was used for removing the oil, and in order to avoid cleaning the pipette so often the following expansion was added to the first one: $(P-p)+(P-p_1)+(P-p_2)+(P-p_3)$, etc.

For every 10° of temperature the expansion of the oil was weighed. The heating was done in a large water-bath very slowly, and the temperature of the water held for some time at the point of the test, so as to be sure that the fluid inside the bottle had reached the same temperature as the water surrounding it.

In the calculation of the table, as sufficient for all practical purposes, I took the coefficient of expansion to be equal or the same during 10° of temperature. As, for instance, in 30° Baumé oil the table shows:

0° temperature,	0.980330 volume, when it should be	0.980330 volume.
	293	287
1° temperature,	0.980623 volume, when it should be	0.980617 volume.
	293	289
2° temperature,	0.980916 volume, when it should be	0.980906 volume.
	293	290
3° temperature,	0.981209 volume, when it should be	0.981196 volume.
	293	291
4° temperature,	0.981502 volume, when it should be	0.981487 volume.
	293	292
5° temperature,	0.981795 volume, when it should be	0.981779 volume.
	293	294
6° temperature,	0.982088 volume, when it should be	0.982073 volume.
	293	295
7° temperature,	0.982381 volume, when it should be	0.982368 volume.
	293	296
8° temperature,	0.982674 volume, when it should be	0.982664 volume.
	293	297
9° temperature,	0.982967 volume, when it should be	0.982961 volume.
	293	299
10° temperature,	0.983260 volume, when it should be	0.983260 volume.
	306	300
11° temperature,	0.983566 volume, when it should be	0.983560 volume.
	306	301
12° temperature,	0.983872 volume, when it should be	0.983861 volume.

I deemed it necessary to call your attention to this fact.

From these experiments it appears that the expansions of the oils increase very perceptibly with the rise of the temperature and also with the decrease of specific gravity; that is, lighter oils expand more readily than heavier oils. The cold-test oils do not seem to differ in this respect from oils which do not stand the cold.

These tables have been found sufficiently accurate for all practical purposes, and are very valuable in handling the great variety of oils produced in that region.

On pages 116 to 133, inclusive, will be found another set of tables, compiled by Dr. S. A. Lattimore, of the University of Rochester, New York, for the use of the Vacuum Oil Company of Rochester, and kindly furnished by those gentlemen for publication. These tables show first the quantity of oil in gallons corresponding to a given weight of oil of different degrees of Baumé's hydrometer, all computed for 60° of temperature. By the use of the first set of tables the volume of a gallon of oil at any temperature between zero and 130° F. can be ascertained if the specific gravity is known at 60° F., while by the use of the second set the number of gallons in a barrel or car of petroleum can be ascertained by weighing if the specific gravity is known at 60° F.

The temperature at which natural petroleums will congeal or become partially solid is an important item in their value for purposes of lubrication, the oils of the Mecca and Franklin districts being particularly valuable in this respect. Great diversity of quality in this particular is observed in the oils of West Virginia, wells in immediate proximity furnishing oils as unlike as possible. The cause of this difference has never been properly investigated, and is only a matter of conjecture; at the same time it is one of the most important questions connected with the heavy-oil trade. Many of the wells of eastern Kentucky yield heavy oils of remarkable and uniformly excellent quality in this respect.

Section 2.—THE MANAGEMENT OF PIPE-LINES.

The bulk of the petroleum trade at the present time is conducted through the pipe-lines and their certificates. The entire product of the Belden and the Mecca districts is handled in barrels in small lots. A considerable portion of the Franklin heavy oil and a small part of that of West Virginia is also handled in the same manner. A smaller proportion of the medium and light oils of West Virginia and southern Ohio, as also of the Smith's Ferry district, is sold by the producers direct to the refiners in barrels, and an insignificant proportion of the product of the Oil creek and upper and lower Allegheny districts finds a market in the same way. Such oil is usually rolled upon a frame over a tank, and is emptied from the barrels into the tank. Hence it is called dump oil. Many thousands of barrels of this oil are gathered in the older and nearly exhausted portions of the oil-fields by middlemen, who divide with the producers the cost of piping, paying them about 10 cents per barrel more than the market price. These middlemen dispose of the oil in car-load lots, and usually have a rack for loading one or more cars. A still larger though insignificant portion of the light-oil product is brought out to the railroad by private pipe-lines and is loaded into cars at private racks in small lots of a few car-loads each. This line of business is usually carried on along Oil creek and the Allegheny river between Titusville, Tidioute, and Brady's bend.

The method of handling petroleum by the pipe-lines is substantially the same for all located within the region producing light oils, with perhaps this exception: that while the smaller companies are incorporated and are legally "common carriers", their business is conducted more like that of private individuals, while that of the United Pipe Lines and the Tide-Water Pipe Company is of a more general public nature and interest. The following description of the method of business adopted by the United Pipe Lines will therefore apply to all of the incorporated pipe-line companies: When oil is received from a well into the lines of the company, the amount is ascertained by a joint measurement made by the representative of the owner of the well and the pipe-line, and is passed to the credit of the former on the books of the company, less 3 per cent., to cover losses to points of delivery. Such oil is held in the custody of the line, subject to the order of the owner, precisely like a deposit in bank, and is transferable on a written order. Upon the signature by the owner of a proper order for the whole or any part of his credit balance, whether such balance is obtained by transfer or production, such order will be marked "accepted" by an authorized agent of the company, and thereafter is known in the trade as an "acceptance" or "certificate", and, like a certified check, is negotiable. As the oil exchanges only deal in certificates of the value of 1,000 barrels, they are, so far as is possible, made of that amount; but those for less amounts are sold to the refiners for immediate use, and do not pass into the speculative trade. All persons holding credit balances are entitled, upon payment of proper charges, to have their oil loaded into cars or barges or delivered into tanks, to be disconnected from the lines. All oil, when received from the wells, at once loses its identity and becomes part of the common stock of the line; no holder of a credit balance can therefore claim the identical oil that entered the line from his tank or well.

Producers' credit balances are held free of storage for thirty days, after which time, unless the owner have tankage upon the line, they are chargeable at the rate of 1¼ cents per barrel per month, equal to $12 50 per 1,000 barrels, until removed or transferred. All credit balances obtained by transfer, unless protected by tankage, are subject to the same storage charge until removed. As all the tankage is now practically owned by the lines, this charge is now substantially uniform on all certificates, equal to $150 on 1,000 barrels for one year.

Parties owning iron tanks can have them connected with the line by signing contracts which entitle them to carry oil either in credit balances or certificates, free of storage, to the capacity of their tank, subject to a shrinkage charge of one-fourth per cent. per month, payable in oil. The capacity of such tank is subject to the owner, and can only be temporarily used by the company. Upon demand by the owner of a credit balance for the delivery of his oil, a pipeage charge of 20 cents per barrel must be paid. The term "shipper" is applied in the trade to parties removing oil from the custody of the line. The Tide-Water Pipe Company insures the oil of its patrons; but the United lines mutually insure, as has been before mentioned, and assess the loss upon the holders of certificates.

Since the Tide-Water Pipe Company successfully laid their line from Rixford to Williamsport (now being carried through to Chester, Pennsylvania) another trunk line has been laid to Jersey City. These lines have not made public their charges for conveying oil out of the oil region. The united lines gather oil into tanks and at convenient points of shipment, but do not convey it out of the oil region. The income of these corporations is made up of pipeage fees and storage fees, the former being paid when the oil is removed from the line, and the latter at least once in six months. The term "old oil", used in the exchanges, refers to certificates of pipe-lines on which storage charges have not been paid up to date. Thus, if A holds a certificate of the United Pipe Lines on which storage charges had been paid up to any given previous date, and B bought from him on exchange 1,000 barrels of United oil, storage paid, and A should offer him said certificate, B would say, "That is 'old oil', A; you will have to freshen it." So A would go to the pipe-line office and pay the storage on the certificate up to the date of the transaction, and it would be termed "fresh oil". The line attaches a slip to the certificate showing the date to which storage has been paid.

SECTION 3.—BROKERAGE.

The issuing of certificates by the pipe companies has made speculation in oil, brokerage, and oil exchanges possible to an extent vastly beyond an actual trade in the oil itself. The broker buys or sells for others and charges about $2 50 per thousand barrels for his services. On a market without much fluctuation he also agrees to deliver to customers at a stipulated price a certain amount of oil either on demand or at a fixed time, and receives therefor an amount somewhat less than the storage fees; but he does not purchase until the demand for it is made. If oil falls mean time, he profits; if it rises, he loses; and if the price remains unchanged, he profits to the extent of the money paid him in lieu of storage money that would be paid the pipe company if he purchased the oil. The speculator in oil, therefore, who buys "futures" signs a contract with his broker and pays him his brokerage fees as a buyer and some sum less than $150 per year per thousand barrels of oil. The speculator, who buys certificates if he does not own tankage, pays his broker's fees as a buyer, and also $150 per year per thousand barrels, together with whatever sum may be required to purchase oil to pay the assessments for losses by fire or other accident, and interest on the amount invested. If he owns tankage, in lieu of the $150 per thousand barrels for storage he pays $30 for evaporation and the interest on $260 (the cost of a thousand barrels of tankage), which should be estimated at not less than 20 per cent., together with the other expenses above mentioned.

The fluctuations in the price of petroleum during the census year rendered a speculative investment in the article an object of exciting interest. June 1, 1879, was Sunday. The market opened on the 2d at 74⅜ cents per barrel. It continued to fall, with little disposition to rally, until on the 17th it closed at 64⅜; and after fluctuating between 65 and 68 for four days, it reached 75, and dropped to 69⅜ on the 25th. It hovered about 70 until the 9th of August, when it began to fall, reaching 64⅜ on the 27th. A slight rally held it at about 66 until the 7th of September, when an upward movement began, reaching 96¼ on October 9. It remained near 91 until the 10th of November, when it again moved upward, reaching $1 27½ on the 21st, closing that day at $1 22½. On the following day it ranged between $1 22½ and $1 10⅝, closing at $1 18⅛, from which it rallied, reaching on the 2d of December $1 28⅛. Between the 10th and 18th it ranged between $1 27½ and $1 10, and fluctuated greatly between $1 18 and $1 09 from this time to January 15, 1880, when it went down in three days to $1 05, and steadily declined, with scarce a rally, till, on March 9, it touched 85⅝. It hovered between 85 and 90 till April 6, when it again commenced to decline, reaching 71¼ on the 21st. On the 5th of May it closed at 72½, and by the 26th had again reached the latitude of 93¾, closing on the 31st at 98¾. It will thus be seen that the certificates of oil in tank were worth that year from 64⅜ cents to $1 28⅛ per barrel, and this variation of almost 100 per cent. occurred between August 27 and December 2, an interval of only sixty-eight days. If a man wants a quantity of oil for refining the transaction becomes one of the simplest possible. He buys certificates to the amount required, and calls upon the pipe company to deliver the oil whenever he chooses to provide tanks, cars, or barges to receive it, and after the pipeage of 20 cents per barrel is paid the company delivers the oil.

The price of Franklin first-sand oil averaged during the census year $3 82 per barrel of 42 gallons; that of second-sand crude for the same time varied very slightly from that of third-sand oil. The price of Mecca oil ranged from $7 to $9 per barrel; Smith's Ferry amber oil averaged $1 50 per barrel. The price of West Virginia oils varied from $1 per barrel for light to $9 per barrel for the heaviest oils produced.

The business of the West Virginia Transportation Company, though far smaller in bulk, is much more intricate in detail than that of the large companies controlling the vast interests of the Pennsylvania oil regions. As already mentioned, their oil is so variable in character that its quality has to be determined by an inspector. The following is a copy of the certificate used by this company, and the rules of the company printed upon the back of it:

Dept. C, No. 2694.

THE WEST VIRGINIA TRANSPORTATION COMPANY,
Parkersburg, W. Va., August 8, 1881.

Received from Excelsior well, West Va. O. & O. L. Co., tract for account of royalty, under and subject to the charges, terms, and conditions on the back of this receipt, as a part thereof, No. —— barrels (of 40 gallons each) of $32\frac{3}{10}°$ crude oil, for transportation through pipe-line in bulk with C grade ($31\frac{6}{10}$ to $32\frac{9}{10}$ gravity) to our tanks at Volcano, West Virginia, and for delivery by oil of like grade, or gravity, in lots of 500 barrels or over at Parkersburg, West Virginia, (unavoidable delays excepted), to the order of Geo. Washington, at the rate of 35 cents per barrel, including therein all charges for inspecting, grading, and measuring said oil, and certifying in the receipt therefor the amount, grade, and gravity, and liability under and by reason of said certificate.

THE WEST VIRGINIA TRANSPORTATION CO.,
By M. C. C. CHURCH, *Secretary*.

Attest: CHAS. A. BUKEY.

(Stamped across the face:) Canceled August 1, 1881.
(On the margin:) Not negotiable unless signed by the secretary of the company.

FORM NO. 5.

The terms and conditions upon which the within mentioned oil is held by the West Virginia Transportation Company are as follows:

In receiving the within oil, the water and sediment contained therein, as per the following inspector's certificate, have been first deducted, and the following percentages of oil have been reserved to cover losses for evaporation and waste in receiving, transporting,

and delivering the same; the within receipt, therefore, covers the net amount only. On light and A grades two and one-half per cent.; on B and C grades two per cent.; and on heavier oils one and one-half per cent. (See below for variation in case of local and special shipments.)

I certify that I have inspected the within oil, and that it contained ½ per cent. of water and sediment at the time of shipment.

HENRY CASKIN, *Inspector.*

The company shall not be responsible or liable for loss by fire or unavoidable accidents; but any such loss shall be assessed, *pro rata*, upon the total amount of outstanding certificates of oil, of like grade of the within, held by the company at the time such loss may occur.

The company shall have a lien upon all the within mentioned oil for all charges mentioned in this receipt. These charges shall be made upon the net quantity of oil received by the West Virginia Transportation Company (said quantity being mentioned in the face of this receipt), and the computation thereof to be made from the date of this receipt.

The following percentages of the net amount of oil received shall be deducted to cover losses by evaporation when held in tankage, to wit: On light and A grades, one per cent. per month or part of a month; on B and C grades, three-fourths of one per cent. per month or part of a month; on heavier oils, one-half of one per cent. per month or part of a month.

Monthly statements of the company's oil account will be made; and any gains arising from the above reservations, on account of waste and evaporation, will be returned, *pro rata*, in certificate oil, to shippers, to July 1 of each and every year during the continuance of this arrangement.

Freight and other charges are due and payable on receipt of the oil in the company's tankage at Volcano and Cochran's, West Virginia, and at Petrolia, Ohio. If said charges are not settled within fifteen days from the date of this receipt, storage will be charged at the rate of 2 cents per barrel per month or part of a month from said date. If the oil is not removed within three months from the date aforesaid, the company shall have right to remove and store the same at the expense of the consignee, and the right to sell said oil, or such part thereof as may be necessary, at public auction to the highest bidder, to pay the advances made and charges due to it, together with the costs of sale. Such sale to be made upon the premises of the company upon at least ten days' notice by advertising in newspapers published at Parkersburg, West Virginia, and Marietta, Ohio.

In receiving and making delivery of oils shipped by the company, the water and sediment contained therein shall be determined by mixing an average sample with an equal quantity of benzine, and subject the mixture to 120° F., in a graduated glass vessel, for not less than 6 hours, after which the mixture cools and settles not less than two hours for light grade, 3 hours for A grade, 4 hours for B grade, 6 hours for C grade, 8 hours for D grade, and 18 hours for heavier grades.

No allowance made on account of condition in making delivery of the within oil.

Note.—The foregoing applies to regular shipments, to wit: Shipments net by pipe-line to Parkersburg, West Virginia, or to Petroleum, West Virginia, or to Petrolia, Ohio, or to Cochran's, West Virginia.

SPECIAL SHIPMENTS.—The company will take special shipments of oil, in lots of 500 barrels or over, under the conditions expressed herein, except as modified as follows: First. Tankage shall be furnished at the point of destination and possession retained by the company until the final delivery of the shipment. Second. The company delivers all the oil, water, and sediment received by it and guarantees that the loss of actual oil shall not exceed the above reservations. Third. Special shipment certificates will be issued and charges will be made upon the gross amount of oil, water, and sediment received for transportation.

Note.—Special shipments are shipments by pipe-line, in gross, to Parkersburg, West Virginia, or to Petroleum, West Virginia.

LOCAL SHIPMENTS.—The company will take local shipments of oil, in lots of not less that 50 barrels, charging therefor at the rate of 10 cents per barrel. Local shipments to be under the same conditions in other respects as expressed above for special shipments.

Note.—Local shipments are shipments made in gross, and are confined to points in the Volcano oil district. When regular shipments are stopped *in transitu* they become local shipments, and charges will be made on the gross amount received at the well, and not on the net amount, as per face of regular shipment certificates. In all such cases said certificates must be surrendered and canceled and local shipment certificates issued for the gross amount at the well, as aforesaid; the delivery as to amount to be made, however, according to the terms of the regular shipment certificates surrendered.

The acceptance and retention of this receipt shall be regarded as an agreement on the part of the owner of said oil to all its terms and conditions, which shall be equally binding on all subsequent holders hereof.

Deliver to the order of ——.

The charges for pipeage from the wells in Volcano district to Parkersburg, West Virginia, are 35 cents per barrel of 40 gallons each; to the Baltimore and Ohio railroad, 30 cents; to Cochran's Landing, Ohio river, 30 cents; and local shipments to points within the oil districts, 10 cents. From Cow run, Ohio, to Petrolia, on the Ohio river, the rate is 30 cents. If oil remains in their tankage over 15 days, the charge for storage is 2 cents per barrel per month or part of a month from date, unless the freight charges are paid when storage is remitted. So far as the principal and general use of the certificates of this company is concerned, they become what they indicate—mere mediums between the consignor and consumer or refiner. Sometimes, however, they are used by the producers as collateral security for their notes in the local banks. In some instances also they have been purchased by investors as a speculation and held for a rising market, but such cases are exceptional.

SECTION 4.—PETROLEUM AS AN ARTICLE OF FOREIGN COMMERCE.

The foreign trade in petroleum centers in New York, Philadelphia, and Baltimore, with a very large proportion of the whole in New York. The exports consist of crude petroleum, the different varieties of illuminating oil, naphtha, and residuum. This trade is largely controlled by the New York produce exchange. The following rules, which indicate the general methods upon which the business is conducted, are taken from their report for 1879:

CRUDE PETROLEUM.

RULE 4. Crude petroleum shall be understood to be pure, natural oil, neither steamed nor treated, free from water, sediment, or any adulteration, of the gravity of 43° to 48° Baumé.

RULE 5. When crude petroleum is sold in bulk, the quantity shall be ascertained by tank measurement at the time of delivery.

RULE 6. Crude petroleum in barrels shall be sold by weight at the rate of 6½ pounds net to the gallon.

RULE 7. In the absence of any stipulation, crude petroleum, when sold in barrels, shall be understood to mean, so far as regards packages, such packages as were originally refined petroleum barrels, whose last contents was crude petroleum, refined petroleum, or naphtha.

RULE 8. When contracts for crude petroleum call for second-hand refined petroleum barrels (*i. e.*, barrels whose last contents have been refined petroleum or naphtha) the sellers shall have the privilege of substituting new barrels, but they shall be glued.

RULE 9. The weighing and verification of crude petroleum shall be governed by the rules applicable thereto under the head of refined petroleum.

REFINED PETROLEUM.

RULE 10. Refined petroleum shall be standard white, or better, with a burning test of 110° F. or upward, and of a specific gravity not below 45° Baumé.

RULE 11. The burning test of refined petroleum shall be determined by the use of the Saybolt electric instrument, and shall be operated in arriving at a result as follows: In 110° and upward the flashing points, after the first flash (which will generally occur between 90° and 95°), shall be taken at 95°, 100°, 104°, 108°, 110°, 112°, and 115°; in 120° and upward, after first flash, at 100°, 105°, 110°, 115°, 118°, 120°, 122°, and 125°; in 130° and upward, every 5° until burning point is reached.

RULE 12. When refined petroleum is sold in bulk, the quantity shall be ascertained by measurement on the decks of the tank-boats.

RULE 13. Refined petroleum shall be delivered in blue, well-painted barrels, with white heads. Barrels shall be well glued and filled within 1 or 2 inches of the bung.

RULE 14. Refined petroleum in barrels shall be sold by weight at the rate of 6½ pounds net to the gallon.

RULE 15. The tares of refined petroleum in barrels shall be weighed by half pounds and gross weight by pounds.

RULE 16. The gross weight of packages for refined petroleum shall be not less than 360 pounds nor more than 415 pounds, and the actual gross weight shall be plainly marked thereon.

RULE 17. Barrels shall be made of well-seasoned white-oak timber, and shall be hooped not lighter than as follows: Either with six iron hoops, the head hoop 1¾ inches wide, No. 16 gauge, English standard, the quarter hoop 1½ inches wide, No. 17 gauge, and the bilge-hoop 1¾ inches wide, No. 16 gauge; or with eight iron hoops, the head-hoop 1¾ inches wide, No. 17 gauge, the collar-hoop 1½ inches wide, No. 17 gauge, the quarter-hoop 1½ inches wide, No. 18 gauge, and the bilge-hoop 1½ inches wide, No. 18 gauge. But all old barrels of which the gross weight is less than 395 pounds may be hooped with six iron hoops 1½ inches wide, excepting the chine hoop, which shall be 1¾ inches wide.

RULE 18. Buyers may test, at their own expense, the correctness of the gross weight or gauge of the whole or part of any lot delivered, and the average shortage found on a portion of not less than 10 per cent. shall be taken as the average amount to be deducted from the lot.

RULE 19. The tare shall be plainly marked upon each barrel before it is filled. Buyers may test the accuracy of the tare so marked to the extent of 5 per cent. of the lot, and the average difference between the tare thus ascertained and the marked tare on the barrels tested shall be accepted as the average difference on the entire lot. Any excess of tare so discovered shall be allowed buyer.

NAPHTHA.

RULE 20. Naphtha shall be water-white and sweet, and of gravity of from 68° to 73° Baumé.

RULE 21. When naphtha is sold in bulk, the quantity shall be ascertained by measurement on the decks of the tank-boats.

RULE 22. Naphtha in barrels shall be sold by weight at the rate of 5¾ pounds net to the gallon.

RULE 23. Barrels containing naphtha shall be painted blue, with white heads, and be well glued.

RULE 24. Naphtha shall be weighed, and may be tested by the buyer, as provided in the foregoing rules relating to refined petroleum.

RESIDUUM.

RULE 25. Residuum shall be understood to be the refuse from the distillation of crude petroleum, free from coke and water and from any foreign impurities, and of gravity from 16° to 21° Baumé.

RULE 26. Residuum, when sold in barrels, shall be sold by weight, at the rate of 7½ pounds net per gallon.

RULE 27. Residuum shall be weighed, and may be tested by the buyer, as provided in the foregoing rules relating to refined petroleum.

EMPTY BARRELS.

RULE 28. Unless otherwise stipulated, empty barrels shall be understood to have last contained either refined petroleum or naphtha.

RULE 29. Barrels shall be classified according to the use for which they are fitted, as follows:

First class shall include all barrels which, if properly coopered, would be fit to carry refined petroleum or naphtha.

Second class shall include barrels which are unfit for refined petroleum or naphtha, but which would, if properly coopered, be fit for crude petroleum.

Third class shall include such barrels as are unfit for either crude, refined petroleum, or naphtha, but which can be used for residuum, if properly coopered.

RULE 30. When barrels which would otherwise be first class have been injured by sand, mold, or water, they shall be placed in the second class.

RULE 32. When barrels have been filled with crude petroleum, and steamed out after shipment to Europe and used for refined oil, such packages shall be placed in the second class.

RULE 33. All empty barrels must have six hoops, and be delivered in form, shooks or staves not being a good delivery.

CONTRACTS AND DELIVERIES.

RULE 35. All deliveries and contracts for delivery of petroleum and its products under these rules shall be of the production of the United States, unless otherwise specified.

RULE 36. All settlements of contracts for refined petroleum and naphtha shall be on the following basis: In barrels, on 50 gallons; in bulk, on 45 gallons. All settlements of contracts for crude petroleum shall be on the following basis: In barrels, on 48 gallons; in bulk, on 42 gallons.

RULE 37. All cooperage shall be in prime shipping order. Tar and pitch barrels shall be excluded, except for residuum.

RULE 38. When the capacity of the vessel exceeds or falls short of the amount specified in the contract, including the margin, then the specified amount shall be delivered. In determining the capacity of the vessel, barrels of 50 net gallons capacity in case of refined petroleum and naphtha, barrels of 48 net gallons capacity in case of crude petroleum, and barrels of 45 net gallons capacity in case of residuum shall be the basis for settlement.

The inspection of petroleum and its products for export is an important business in New York city, Philadelphia, and Baltimore. Mr. A. Bourgougnon has read before the American Chemical Society several papers relating to this inspection. He refers to the fact that the petroleum of the New York market is a mixture of oils from a great many wells, and remarks that the specific gravity of the New York crude oil ranges from 0.790 to 0.800 = 48° to 46° B. at 15° C.

The coefficient of expansion of the crude oil varies from 0.00082 to 0.00086, according to the gravity of the oil. For the products of distillation the following can be generally adopted:

Under 0.700 gravity at 15° C	0.00090
0.700 to 0.750 gravity at 15° C	0.00085
0.750 to 0.800 gravity at 15° C	0.00080
0.800 gravity at 15° C	0.00070

The knowledge of these coefficients is important, as it aids in calculating the empty space which must be allowed in the vessels containing the oil. This space will be—

$$V. K. 50,$$

V representing the volume of the oil, K the coefficient of expansion, and 50 the number of degrees of temperature through which the oil may change.

Generally the inspectors examine the density, the odor, and how the oil feels with the fingers, and make a fractional distillation in tenth parts, giving a report stating that the oil does not contain more than 17 per cent. of naphtha. He states further that the separation of the distillate into hundredths instead of tenths is much to be preferred, as the proportion of naphtha can then be determined with exactness; "and this determination is very important to the buyer, since the crude oil is taxed in foreign countries according to the quantity of naphtha contained in it."

The crude oil of the New York market will generally furnish from 12 to 15 per cent. of naphtha at 0.700 specific gravity, 9 to 12 per cent. of benzine at 0.730 specific gravity, and about 60 per cent. of burning oil at 0.795 specific gravity. The residuum contains 2½ per cent. of dry paraffine, calculated for the quantity of oil submitted to distillation. (*a*)

In another communication he thus describes an ingeniously contrived instrument for determining the amount of naphtha of 0.700 gravity in crude petroleum:

I employ an instrument made on the same principle and of the same shape as an hydrometer, which I call a *naphthometer.* To make the graduation of this instrument I proceed as follows: The specific gravity of commercial naphtha being 0.700 at 15° C., it is first necessary to have such naphtha. This naphtha being at a temperature of 15° C., the naphthometer is immersed in it, and on the stem at the point of intersection of the liquid the number 15 is written. The same naphtha is brought to a temperature of 20° C., and on the stem, as above, the number 20 is written; the temperature of the naphtha is again increased to 25° C., and the number 25 is written on the stem at the point of intersection, and so on, in order that the temperature indicated by the thermometer (when immersed in naphtha of 0.700 at 15° C.) will be always in accordance with the figures marked on the stem. For example, if I have a sample of naphtha of which the density is 0.700 at 15° C., but supposing that the actual temperature be 20° C., the naphthometer will indicate 20 both by the thermometer and on the stem at the point of intersection with the liquid. Now, to determine the percentage of naphtha in crude petroleum, I distill, say 300 c. c., and collect the distillate in a glass cylinder divided into c. c., in which glass the naphthometer has been previously placed. The temperature of the distillate, and if, *e. g.*, the temperature be 25° C., the distillation is continued until the point marked 25 on the stem intersects with the liquid. At this moment the naphtha has a specific gravity of 0.700 at 15° C., as I have verified by several experiments. Removing the naphthometer from the jar, cooling to 15° C., and reading the number of c. c. obtained, and dividing by 3, I obtain finally the percentage of naphtha at 0.700 density and at the temperature of 15° C. contained in the crude oil. (*b*)

The increase in the bulk of petroleum and of all its products, due to an increase of temperature, occasions a great deal of trouble in measuring these articles in bulk. In barrels and small packages the difficulty is obviated by weighing. Preisser, of Rouen, in 1840, investigated a case in which a certain amount of oil (seed and fish) was stored in winter and measured in summer, when an excess was discovered, and the parties storing were charged with fraud. He found that the oil increased in volume at a certain ratio for each degree of temperature. (*c*) M. Henri St. Claire Deville first stated that American petroleum increases in bulk 0.01 for every 10° C. Later it has been discovered that the ratio of expansion varies with the specific gravity of the oil and also with the temperature. The table on pages 111 to 115, inclusive, has been computed for the specific gravity of crude oil up to 45° B.

a J. Am. Chem., vii, 81. *b Ibid.*, p. 123. *c Jour. F. Inst.*, xxix, 130.

This does not embrace illuminating oils or naphthas, but is approximately correct for the dense oils below 45°. Mr. Gustavus Pile offers the following suggestion of a method of universal application to crude petroleum and all petroleum products: (*a*)

I was asked a short time ago by a gentleman in the coal-oil trade to furnish him with some sort of apparatus with which he could readily estimate the number of gallons of oil there would be in a tank gauged at any temperature if the temperature were reduced to 60° F. The rate of expansion of most of the petroleum products being considerable, the difference in measurement at various temperatures often becomes too great to be unnoticed. In the case of benzine of 68° B., the expansion from 30° to 90° F. amounted to 50 parts in a 1,000. The solution of this problem appears to be best made by observing the specific gravity as it would stand at different temperatures, and calculating from the variation in the gravity the amount of expansion in bulk. If we have gauged a tank holding oil and find it to hold, at 90° temperature, 12,000 gallons, and desire to know how much that would measure if reduced to 60° temperature, we must first note the gravity at the two temperatures, 60° and 90°, and the calculation will then be as follows: Say the gravity at 90° = 0.7900 and at 60° = 0.8025. The gravity at 90° is to be divided by the gravity at 60°, thus $\frac{7900}{8025}$, which will give the measure at 60° of one gallon, and by multiplying this by 12,000, $\frac{7900}{8025} + 12,000 = 11,812$ gallons, we have the measure at 60° of the whole amount. The difference of 188 gallons between the measure at 60° and that at 90° expresses the expansion caused by that increase of temperature.

In order to obtain correct results by this method, it would be necessary to use hydrometers made with a specific gravity scale and with the degrees sufficiently far apart to be able to read to single degrees, or also to use a specific gravity bottle, which, of course, will always give the best result.

I am not acquainted with any method that may be in use among dealers, but the plan here suggested will give accurate conclusions, and where it is found necessary to be particular can be used with confidence.

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a *Oil and Drug News.*

TABLE OF EXPANSION OF THE WEST VIRGINIA NATURAL OILS.

[*GRAVITIES* 28° *TO* 45°, *FROM ZERO TO* 130° *F., WITH THE UNIT AT* 60° *TEMPERATURE.*]

Calculated by JUL. SCHUBERT, *Engineer.*

The expansion of the West Virginian natural oils is, as the following table shows, by no means very small, and has in a large number of cases worked to the disadvantage of both producers and dealers. It therefore became desirable to have the expansion of the oils established, and carefully conducted experiments, according to the rule laid down by Professor Gay-Lussac for testing the expansion of liquids, and calculations made corresponding to the formula of the same author, have furnished the following table.

The coefficient of expansion of the glass entering into the calculation has been adopted as being 0.000026.

The expansion of the oils increases with the temperature and varies with the gravity. The higher oils expand faster than the heavier oils within the same change of temperature. It became necessary, therefore, to establish the scale of expansion for each gravity from 28° to 45°.

As the gravity is measured at 60° temperature, the unit for the volume of the oil has also been taken at 60° F.

The quantity of oil at 60° temperature should be the guide in all business transactions with the West Virginian natural oils.

RULES FOR USE OF THE TABLE.—In order to find the quantity of oil at 60° temperature: Divide the quantity of the oil by the figure found in the table corresponding both to gravity and temperature of the oil.

For instance: 75.63 barrels of 35° oil, measured at a temperature of 26°, would be:

$$\frac{75.63}{0.987394} = 76.59 \text{ barrels of } 35° \text{ oil at } 60°.$$

Or, 81.34 barrels of 33° oil, measured at a temperature of 88°, would be:

$$\frac{81.34}{1.011566} = 80.41 \text{ barrels of } 33° \text{ oil at } 60° \text{ temperature.}$$

TABLE OF EXPANSION OF THE WEST VIRGINIA NATURAL OILS.

Degrees of temperature. (F.)	DEGREES OF GRAVITY.								
	28°.	29°.	30°.	31°.	32°.	33°.	34°.	35°.	36°.
Zero.	0.980810	0.980570	0.980330	0.980060	0.979770	0.979470	0.979170	0.978870	0.978570
1	0.981095	0.980859	0.980623	0.980357	0.980071	0.979776	0.979481	0.979186	0.978891
2	0.981380	0.981148	0.980916	0.980654	0.980372	0.980082	0.979792	0.979502	0.979212
3	0.981665	0.981437	0.981209	0.980951	0.980673	0.980388	0.980103	0.979818	0.979533
4	0.981950	0.981726	0.981502	0.981248	0.980974	0.980694	0.980414	0.980134	0.979854
5	0.982235	0.982015	0.981795	0.981545	0.981275	0.981000	0.980725	0.980450	0.980175
6	0.982520	0.982304	0.982088	0.981842	0.981576	0.981306	0.981036	0.980766	0.980496
7	0.982805	0.982593	0.982381	0.982139	0.981877	0.981612	0.981347	0.981082	0.980817
8	0.983090	0.982882	0.982674	0.982436	0.982178	0.981918	0.981658	0.981398	0.981138
9	0.983375	0.983171	0.982967	0.982733	0.982479	0 982224	0.981969	0.981714	0.981459
10	0.983660	0.983460	0.983260	0.983030	0.982780	0.982530	0.982280	0.982030	0.981780
11	0.983958	0.983762	0.983566	0.983340	0.983095	0.982850	0.982605	0.982360	0.982115
12	0.984256	0.984064	0.983872	0.983650	0.983410	0.983170	0.982930	0.982690	0.982450
13	0.984554	0.984366	0.984178	0.983960	0.983725	0.983490	0.983255	0.983020	0.982785
14	0.984852	0.984668	0.984484	0.984270	0.984040	0.983810	0.983580	0.983350	0.983120
15	0.985150	0.984970	0.984790	0.984580	0.984355	0 984130	0.983905	0.983680	0.983455
16	0.985448	0.985272	0.985096	0.984890	0.984670	0.984450	0.984230	0.984010	0.983790
17	0.985746	0.985574	0.985402	0.985200	0.984985	0.984770	0.984555	0.984340	0.984125
18	0.986044	0.985876	0.985708	0.985510	0.985300	0.985090	0.984880	0.984670	0.984460
19	0.986342	0.986178	0.986014	0.985820	0.985615	0.985410	0.985205	0.985000	0.984795
20	0.986640	0.986480	0.986320	0.986130	0.985930	0.985730	0.985530	0.985330	0.985130
21	0.986952	0.986796	0.986640	0.986454	0.986259	0.986064	0.985869	0.985674	0.985479
22	0.987264	0.987112	0.986960	0.986778	0.986588	0.986398	0.986208	0.986018	0.985828
23	0.987576	0.987428	0.987280	0.987102	0.986917	0.986732	0.986547	0.986362	0.986177
24	0.987888	0.987744	0.987600	0.987426	0.987246	0.987066	0.986886	0.986706	0.986526
25	0.988200	0.988060	0.987920	0.987750	0.987575	0.987400	0.987225	0.987050	0.986875
26	0.988512	0.988376	0.988240	0.988074	0.987904	0.987734	0.987564	0.987394	0.987224
27	0.988824	0.988692	0.988560	0.988398	0.988233	0.988068	0.987903	0.987738	0.987573
28	0.989136	0.989008	0.988880	0.988722	0.988562	0.988402	0.988242	0.988082	0.987922
29	0.989448	0.989324	0.989200	0.989046	0.988891	0.988736	0.988581	0.988426	0.988271
30	0.989760	0.989640	0.989520	0.989370	0.989220	0.989070	0.988920	0.988770	0.988620
31	0.990086	0.989970	0.989854	0.989709	0.989564	0.989419	0.989274	0.989129	0.988984
32	0.990412	0.990300	0.990188	0.990048	0.989908	0.989768	0.989628	0.989488	0.989348
33	0.990738	0.990630	0.990522	0.990387	0.990252	0.990117	0.989982	0.989847	0.989712
34	0.991064	0.990960	0.990856	0.990726	0.990596	0.990466	0.990336	0.990206	0.990076
35	0.991390	0.991290	0.991190	0.991065	0.990940	0.990815	0.990690	0.990565	0.990440
36	0.991716	0.991620	0.991524	0.991404	0.991284	0.991164	0.991044	0.990924	0.990804
37	0.992042	0.991950	0.991858	0.991743	0.991628	0.991513	0.991398	0.991283	0.991168
38	0.992368	0.992280	0.992192	0.992082	0.991972	0.991862	0.991752	0.991642	0.991532
39	0.992694	0.992610	0.992526	0.992421	0.992316	0.992211	0.992106	0.992001	0.991896
40	0.993020	0.992940	0.992860	0.992760	0.992660	0.992560	0.992460	0.992360	0.992260
41	0.993361	0.993285	0.993209	0.993114	0.993019	0.992924	0.992829	0.992734	0.992639
42	0.993702	0.993630	0.993558	0.993468	0.993378	0.993288	0.993198	0.993108	0.993018
43	0.994043	0.993975	0.993907	0.993822	0.993737	0.993652	0.993567	0.993482	0.993397
44	0.994384	0.994320	0.994256	0.994176	0.994096	0.994016	0.993936	0.993856	0.993776
45	0.994725	0.994665	0.994605	0.994530	0.994455	0.994380	0.994305	0.994230	0.994155
46	0.995066	0.995010	0.994954	0.994884	0.994815	0.994744	0.991674	0.994604	0.994534
47	0.995407	0.995355	0.995303	0.995238	0.995173	0.995108	0.995073	0.994978	0.994913
48	0.995748	0.995700	0.995652	0.995592	0.995532	0.995472	0.995412	0.995352	0.995292
49	0.996089	0.996045	0.996001	0.995946	0.995891	0.995836	0.995781	0.995726	0.995671
50	0.996430	0.996390	0.996350	0.996300	0.996250	0.996200	0.996150	0.996100	0.996050
51	0.996787	0.996751	0.996715	0.996670	0.996625	0.996580	0.996535	0.996490	0.996445
52	0.997144	0.997112	0.997080	0.997040	0.997000	0.996960	0.996920	0.996880	0.996840
53	0.997501	0.997473	0.997445	0.997410	0.997375	0.997340	0.997305	0.997270	0.997235
54	0.997858	0.997834	0.997810	0.997780	0.997750	0.997720	0.997690	0.997660	0.997630
55	0.998215	0.998195	0.998175	0.998150	0.998125	0.998100	0.998075	0.998050	0.998025
56	0.998572	0.998556	0.998540	0.998520	0.998500	0.998480	0.998460	0.998440	0.998420
57	0.998929	0.998917	0.998905	0.998690	0.998875	0.998860	0.998845	0.998830	0.998815
58	0.999286	0.999278	0.999270	0.999260	0.999250	0.999240	0.999230	0.999220	0.999210
59	0.999643	0.999639	0.999635	0.999630	0.999625	0.999620	0.999615	0.999610	0.999605
60	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
61	1.000374	1.000378	1.000382	1.000387	1.000392	1.000397	1.000402	1.000407	1.000412
62	1.000748	1.000756	1.000764	1.000774	1.000784	1.000794	1.000804	1.000814	1.000824
63	1.001122	1.001134	1.001146	1.001161	1.001176	1.001191	1.001206	1.001221	1.001236
64	1.001496	1.001512	1.001528	1.001548	1.001568	1.001588	1.001608	1.001628	1.001648
65	1.001870	1.001890	1.001910	1.001935	1.001960	1.001985	1.002010	1.002035	1.002060

TABLE OF EXPANSION OF THE WEST VIRGINIA NATURAL OILS—Continued.

Degrees of gravity.									Degrees of temperature. (F.)
37°.	38°.	39°.	40°.	41°.	42°.	43°.	44°.	45°.	
0.978210	0.977850	0.977490	0.977130	0.976770	0.976390	0.976020	0.975660	0.975240	Zero.
0.978537	0.978183	0.977829	0.977475	0.977121	0.976747	0.976383	0.976029	0.975616	1
0.978864	0.978516	0.978168	0.977820	0.977472	0.977104	0.976746	0.976398	0.975992	2
0.979191	0.978849	0.978507	0.978165	0.977823	0.977461	0.977109	0.976767	0.976368	3
0.979518	0.979182	0.978846	0.978510	0.978174	0.977818	0.977472	0.977136	0.976744	4
0.979845	0.979515	0.979185	0.978855	0.978525	0.978175	0.977835	0.977505	0.977120	5
0.980172	0.979848	0.979524	0.979200	0.978876	0.978532	0.978198	0.977874	0.977496	6
0.980499	0.980181	0.979863	0.979545	0.979227	0.078889	0.978561	0.978243	0.977872	7
0.980826	0.980514	0.980202	0.979890	0.979578	0.979246	0.978924	0.978612	0.978248	8
0.981153	0.980847	0.980541	0.980235	0.979929	0.979603	0.979287	0.978981	0.978624	9
0.981480	0.981180	0.980880	0.980580	0.980280	0.979960	0.979650	0.979350	0.979000	10
0.981821	0.981527	0.981233	0.980939	0.980645	0.980331	0.980027	0.979733	0.979390	11
0.982162	0.981874	0.981586	0.981298	0.981010	0.980702	0.980404	0.980116	0.979780	12
0.982503	0.982221	0.981939	0.981657	0.981375	0.981073	0.980781	0.980499	0.980170	13
0.982844	0.982568	0.982292	0.982016	0.981740	0.981444	0.981158	0.980882	0.980560	14
0.983185	0.982915	0.982645	0.982375	0.982105	0.981815	0.981535	0.981265	0.980950	15
0.983526	0.983262	0.982998	0.982734	0.982470	0.982186	0.981912	0.981648	0.981340	16
0.983867	0.983609	0.983351	0.983093	0.982835	0.982557	0.982289	0.982031	0.981730	17
0.984208	0.983956	0.983704	0.983452	0.983200	0.982928	0.982666	0.982414	0.982120	18
0.984549	0.984303	0.984057	0.983811	0.983565	0.983299	0.983043	0.982797	0.982510	19
0.984890	0.984650	0.984410	0.984170	0.983930	0.983670	0.983420	0.983180	0.982900	20
0.985245	0.985011	0.984777	0.984543	0.984309	0.984055	0.983811	0.983577	0.983304	21
0.985600	0.985372	0.985144	0.984916	0.984688	0.984440	0.984202	0.983974	0.983708	22
0.985955	0.985733	0.985511	0.985289	0.985067	0.984825	0.984593	0.984371	0.984112	23
0.986310	0.986094	0.985878	0.985662	0.985446	0.985210	0.984984	0.984768	0.984516	24
0.986665	0.986455	0.986245	0.986035	0.985825	0.985595	0.985375	0.985165	0.984920	25
0.987020	0.986816	0.986612	0.986408	0.986204	0.985980	0.985766	0.985562	0.985324	26
0.987375	0.987177	0.986979	0.986781	0.986583	0.986365	0.986157	0.985959	0.985728	27
0.987730	0.987538	0.987346	0.987154	0.986962	0.986750	0.986548	0.986356	0.986132	28
0.988085	0.987899	0.987713	0.987527	0.987341	0.987135	0.986939	0.986753	0.986536	29
0.988440	0.988260	0.988080	0.987900	0.987720	0.987520	0.987330	0.987150	0.986940	30
0.988810	0.988636	0.988462	0.988288	0.988114	0.987920	0.987736	0.987562	0.987359	31
0.989180	0.989012	0.988844	0.988676	0.988508	0.988320	0.988142	0.987974	0.987778	32
0.989550	0.989388	0.989226	0.989064	0.988902	0.988720	0.988548	0.988386	0.988197	33
0.989920	0.989764	0.989608	0.989452	0.989296	0.989120	0.988954	0.988798	0.988616	34
0.990290	0.990140	0.989990	0.989840	0.989690	0.989520	0.989360	0.989210	0.989035	35
0.990660	0.990516	0.990372	0.990228	0.990084	0.989920	0.989766	0.989622	0.989454	36
0.991030	0.990892	0.990754	0.990616	0.990478	0.990320	0.990172	0.990034	0.989873	37
0.991400	0.991268	0.991136	0.991004	0.990872	0.990720	0.990578	0.990446	0.990292	38
0.991770	0.991644	0.991518	0.991392	0.991266	0.991120	0.990984	0.990858	0.990711	39
0.992140	0.992020	0.991900	0.991780	0.991660	0.991520	0.991390	0.991270	0.991130	40
0.992525	0.992411	0.992297	0.992183	0.992069	0.991936	0.991812	0.991698	0.991565	41
0.992910	0.992802	0.992694	0.992586	0.992478	0.992352	0.992234	0.992126	0.992000	42
0.993295	0.993193	0.993091	0.992989	0.992887	0.992768	0.992656	0.992554	0.992435	43
0.993680	0.993584	0.993488	0.993392	0.993296	0.993184	0.993078	0.992982	0.992870	44
0.994065	0.993975	0.993885	0.993795	0.993705	0.993600	0.993500	0.993410	0.993305	45
0.994450	0.994366	0.994282	0.994198	0.994114	0.994016	0.993922	0.993838	0.993740	46
0.994835	0.994757	0.994679	0.994601	0.994523	0.994432	0.994344	0.994266	0.994175	47
0.995220	0.995148	0.995076	0.995004	0.994932	0.994848	0.994766	0.994694	0.994610	48
0.995605	0.995539	0.995473	0.995407	0.995341	0.995264	0.995188	0.995122	0.995045	49
0.995990	0.995930	0.995870	0.995810	0.995750	0.995680	0.995610	0.995550	0.995480	50
0.996391	0.996337	0.996283	0.996229	0.996175	0.996112	0.996049	0.995995	0.995932	51
0.996792	0.996744	0.996696	0.996648	0.996600	0.996544	0.996488	0.996440	0.996384	52
0.997193	0.997151	0.997109	0.997067	0.997025	0.996976	0.996927	0.996885	0.996836	53
0.997594	0.997558	0.997522	0.997486	0.997450	0.997408	0.997366	0.997330	0.997288	54
0.997995	0.997965	0.997935	0.997905	0.997875	0.997840	0.997805	0.997775	0.997740	55
0.998396	0.998372	0.998348	0.998324	0.998300	0.998272	0.998244	0.998220	0.998192	56
0.998797	0.998779	0.998761	0.998743	0.998725	0.998704	0.998683	0.998665	0.998644	57
0.999198	0.999186	0.999174	0.999162	0.999150	0.999136	0.999122	0.999110	0.999096	58
0.999599	0.999593	0.999587	0.999581	0.999575	0.999568	0.999561	0.999555	0.999548	59
1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	60
1.000418	1.000424	1.000430	1.000436	1.000442	1.000449	1.000456	1.000463	1.000470	61
1.000836	1.000848	1.000860	1.000872	1.000884	1.000898	1.000912	1.000926	1.000940	62
1.001254	1.001272	1.001290	1.001308	1.001326	1.001347	1.001368	1.001389	1.001410	63
1.001672	1.001696	1.001720	1.001744	1.001768	1.001796	1.001824	1.001852	1.001880	64
1.002090	1.002120	1.002150	1.002180	1.002210	1.002245	1.002280	1.002315	1.002350	65

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	28°.	29°.	30°.	31°.	32°.	33°.	34°.	35°.	36°.
66	1.002244	1.002268	1.002292	1.002322	1.002352	1.002382	1.002412	1.002442	1.002472
67	1.002618	1.002646	1.002674	1.002709	1.002744	1.002779	1.002814	1.002849	1.002884
68	1.002992	1.003024	1.003056	1.003096	1.003136	1.003176	1.003216	1.003256	1.003296
69	1.003366	1.003402	1.003438	1.003483	1.003528	1.003573	1.003618	1.003663	1.003708
70	1.003740	1.003780	1.003820	1.003870	1.003920	1.003970	1.004020	1.004070	1.004120
71	1.004131	1.004175	1.004219	1.004274	1.004329	1.004384	1.004439	1.004495	1.004550
72	1.004522	1.004570	1.004618	1.004678	1.004738	1.004798	1.004858	1.004920	1.004980
73	1.004913	1.004965	1.005017	1.005082	1.005147	1.005212	1.005277	1.005345	1.005410
74	1.005304	1.005360	1.005416	1.005486	1.005556	1.005626	1.005696	1.005770	1.005840
75	1.005695	1.005755	1.005815	1.005890	1.005965	1.006040	1.006115	1.006195	1.006270
76	1.006086	1.006150	1.006214	1.006294	1.006374	1.006454	1.006534	1.006620	1.006700
77	1.006477	1.006545	1.006613	1.006698	1.006783	1.006868	1.006953	1.007045	1.007130
78	1.006868	1.006940	1.007012	1.007102	1.007192	1.007282	1.007372	1.007470	1.007560
79	1.007259	1.007335	1.007411	1.007506	1.007601	1.007696	1.007791	1.007895	1.007990
80	1.007650	1.007730	1.007810	1.007910	1.008010	1.008110	1.008210	1.008320	1.008420
81	1.008058	1.008142	1.008226	1.008331	1.008437	1.008542	1.008647	1.008763	1.008869
82	1.008466	1.008554	1.008642	1.008752	1.008864	1.008974	1.009084	1.009206	1.009318
83	1.008874	1.008966	1.009058	1.009173	1.009291	1.009406	1.009521	1.009649	1.009767
84	1.009282	1.009378	1.009474	1.009594	1.009718	1.009838	1.009958	1.010092	1.010216
85	1.009690	1.009790	1.009890	1.010015	1.010145	1.010270	1.010395	1.010535	1.010665
86	1.010098	1.010202	1.010306	1.010436	1.010572	1.010702	1.010832	1.010978	1.011114
87	1.010506	1.010614	1.010722	1.010857	1.010999	1.011134	1.011269	1.011421	1.011563
88	1.010914	1.011026	1.011138	1.011278	1.011426	1.011566	1.011706	1.011864	1.012012
89	1.011322	1.011438	1.011554	1.011699	1.011853	1.011998	1.012143	1.012307	1.012461
90	1.011730	1.011850	1.011970	1.012120	1.012280	1.012430	1.012580	1.012750	1.012910
91	1.012155	1.012279	1.012404	1.012559	1.012725	1.012880	1.013035	1.013212	1.013378
92	1.012580	1.012708	1.012838	1.012998	1.013170	1.013330	1.013490	1.013674	1.013846
93	1.013005	1.013137	1.013272	1.013437	1.013615	1.013780	1.013945	1.014136	1.014314
94	1.013430	1.013566	1.013706	1.013876	1.014060	1.014230	1.014400	1.014598	1.014782
95	1.013855	1.013995	1.014140	1.014315	1.014505	1.014680	1.014855	1.015060	1.015250
96	1.014280	1.014424	1.014574	1.014754	1.014950	1.015130	1.015310	1.015522	1.015718
97	1.014705	1.014853	1.015008	1.015193	1.015395	1.015580	1.015765	1.015984	1.016186
98	1.015130	1.015282	1.015442	1.015632	1.015840	1.016030	1.016220	1.016446	1.016654
99	1.015555	1.015711	1.015876	1.016071	1.016285	1.016480	1.016675	1.016908	1.017122
100	1.015980	1.016140	1.016310	1.016510	1.016730	1.016930	1.017130	1.017370	1.017590
101	1.016422	1.016587	1.016762	1.016967	1.017193	1.017399	1.017644	1.017851	1.018077
102	1.016864	1.017034	1.017214	1.017424	1.017656	1.017868	1.018078	1.018332	1.018564
103	1.017306	1.017481	1.017666	1.017881	1.018119	1.018337	1.018552	1.018813	1.019051
104	1.017748	1.017928	1.018118	1.018338	1.018582	1.018806	1.019026	1.019294	1.019538
105	1.018190	1.018375	1.018570	1.018795	1.019045	1.019275	1.019500	1.019775	1.020025
106	1.018632	1.018822	1.019022	1.019252	1.019508	1.019744	1.019974	1.020256	1.020512
107	1.019074	1.019269	1.019470	1.019709	1.019971	1.020213	1.020448	1.020737	1.020999
108	1.019516	1.019716	1.019926	1.020166	1.020434	1.020682	1.020922	1.021218	1.021486
109	1.019958	1.020163	1.020378	1.020623	1.020897	1.021151	1.021396	1.021699	1.021973
110	1.020400	1.020610	1.020830	1.021080	1.021360	1.021620	1.021870	1.022180	1.022460
111	1.020860	1.021075	1.021300	1.021556	1.021842	1.022108	1.022363	1.022680	1.022967
112	1.021320	1.021540	1.021770	1.022032	1.022324	1.022596	1.022856	1.023180	1.023474
113	1.021780	1.022005	1.022240	1.022508	1.022806	1.023084	1.023349	1.023680	1.023981
114	1.022240	1.022470	1.022710	1.022984	1.023288	1.023572	1.023842	1.024180	1.024488
115	1.022700	1.022935	1.023180	1.023460	1.023770	1.024060	1.024335	1.024680	1.024995
116	1.023160	1.023400	1.023650	1.023936	1.024252	1.024548	1.024828	1.025180	1.025502
117	1.023620	1.023865	1.024120	1.024412	1.024734	1.025036	1.025321	1.025680	1.026009
118	1.024080	1.024330	1.024590	1.024888	1.025216	1.025524	1.025814	1.026180	1.026516
119	1.024540	1.024795	1.025060	1.025364	1.025698	1.026012	1.026307	1.026680	1.027023
120	1.025000	1.025260	1.025530	1.025840	1.026180	1.026500	1.026800	1.027180	1.027530
121	1.025478	1.025743	1.026019	1.026335	1.026681	1.027007	1.027313	1.027700	1.028057
122	1.025956	1.026226	1.026508	1.026830	1.027182	1.027514	1.027826	1.028220	1.028584
123	1.026434	1.026709	1.026997	1.027325	1.027683	1.028021	1.028339	1.028740	1.029111
124	1.026912	1.027192	1.027486	1.027820	1.028184	1.028528	1.028852	1.029260	1.029638
125	1.027390	1.027675	1.027975	1.028315	1.028685	1.029035	1.029365	1.029780	1.030165
126	1.027868	1.028158	1.028464	1.028810	1.029186	1.029542	1.029878	1.030300	1.030692
127	1.028346	1.028641	1.028953	1.029305	1.029687	1.030049	1.030391	1.030820	1.031219
128	1.028824	1.029124	1.029442	1.029800	1.030188	1.030556	1.030904	1.031340	1.031746
129	1.029302	1.029607	1.029931	1.030295	1.030689	1.031063	1.031417	1.031860	1.032273
130	1.029780	1.030090	1.030420	1.030790	1.031190	1.031570	1.031930	1.032380	1.032800

TABLE OF EXPANSION OF THE WEST VIRGINIA NATURAL OILS—Continued.

DEGREES OF GRAVITY.									Degrees of temperature. (*F.*)
37°.	38°.	39°.	40°.	41°.	42°.	43°.	44°.	45°.	
1.002508	1.002544	1.002580	1.002616	1.002652	1.002694	1.002736	1.002778	1.002820	66
1.002926	1.002968	1.003010	1.003052	1.003094	1.003143	1.003192	1.003241	1.003290	67
1.003344	1.003392	1.003440	1.003488	1.003536	1.003592	1.003648	1.003704	1.003760	68
1.003762	1.003816	1.003870	1.003924	1.003978	1.004041	1.004104	1.004167	1.004230	69
1.004180	1.004240	1.004300	1.004360	1.004420	1.004490	1.004560	1.004630	1.004700	70
1.004616	1.004682	1.004748	1.004814	1.004880	1.004957	1.005034	1.005112	1.005189	71
1.005052	1.005124	1.005196	1.005268	1.005340	1.005424	1.005508	1.005592	1.005678	72
1.005488	1.005566	1.005644	1.005722	1.005800	1.005891	1.005982	1.006076	1.006167	73
1.005924	1.006008	1.006092	1.006176	1.006260	1.006358	1.006456	1.006558	1.006656	74
1.006360	1.006450	1.006540	1.006630	1.006720	1.006825	1.006930	1.007040	1.007145	75
1.006796	1.006892	1.006988	1.007084	1.007180	1.007292	1.007404	1.007522	1.007634	76
1.007232	1.007334	1.007436	1.007538	1.007640	1.007759	1.007878	1.008004	1.008123	77
1.007668	1.007776	1.007884	1.007992	1.008100	1.008226	1.008352	1.008486	1.008612	78
1.008104	1.008218	1.008332	1.008446	1.008560	1.008693	1.008826	1.008968	1.009101	79
1.008540	1.008660	1.008780	1.008900	1.009020	1.009160	1.009300	1.009450	1.009590	80
1.008995	1.009121	1.009247	1.009373	1.009499	1.009646	1.009793	1.009951	1.010099	81
1.009450	1.009582	1.009714	1.009846	1.009978	1.010132	1.010286	1.010452	1.010608	82
1.009905	1.010043	1.010181	1.010319	1.010457	1.010618	1.010779	1.010953	1.011117	83
1.010360	1.010504	1.010648	1.010792	1.010936	1.011104	1.011272	1.011454	1.011626	84
1.010815	1.010965	1.011115	1.011265	1.011415	1.011590	1.011765	1.011955	1.012135	85
1.011270	1.011426	1.011582	1.011738	1.011894	1.012076	1.012258	1.012456	1.012644	86
1.011725	1.011887	1.012049	1.012211	1.012373	1.012562	1.012751	1.012957	1.013153	87
1.012180	1.012348	1.012516	1.012684	1.012852	1.013048	1.013244	1.013458	1.013662	88
1.012635	1.012809	1.012983	1.013157	1.013331	1.013534	1.013737	1.013959	1.014171	89
1.013090	1.013270	1.013450	1.013630	1.013810	1.014020	1.014230	1.014460	1.014680	90
1.013564	1.013750	1.013937	1.014123	1.014309	1.014526	1.014743	1.014981	1.015209	91
1.014038	1.014230	1.014424	1.014616	1.014808	1.015032	1.015256	1.015502	1.015738	92
1.014512	1.014710	1.014911	1.015109	1.015307	1.015538	1.015769	1.016023	1.016267	93
1.014986	1.015190	1.015398	1.015602	1.015806	1.016044	1.016282	1.016544	1.016796	94
1.015460	1.015670	1.015885	1.016095	1.016305	1.016550	1.016795	1.017065	1.017325	95
1.015934	1.016150	1.016372	1.016588	1.016804	1.017056	1.017308	1.017586	1.017854	96
1.016408	1.016630	1.016859	1.017081	1.017303	1.017562	1.017821	1.018107	1.018383	97
1.016882	1.017110	1.017346	1.017574	1.017802	1.018068	1.018334	1.018628	1.018912	98
1.017356	1.017590	1.017833	1.018067	1.018301	1.018574	1.018847	1.019149	1.019441	99
1.017830	1.018070	1.018320	1.018560	1.018800	1.019080	1.019360	1.019670	1.019970	100
1.018324	1.018570	1.018827	1.019073	1.019320	1.019607	1.019894	1.020212	1.020520	101
1.018818	1.019070	1.019334	1.019586	1.019840	1.020134	1.020428	1.020754	1.021070	102
1.019312	1.019570	1.019841	1.020099	1.020360	1.020661	1.020962	1.021296	1.021620	103
1.019806	1.020070	1.020348	1.020612	1.020880	1.021088	1.021496	1.021838	1.022170	104
1.020300	1.020570	1.020855	1.021125	1.021400	1.021715	1.022030	1.022380	1.022720	105
1.020794	1.021070	1.021362	1.021638	1.021920	1.022242	1.022564	1.022922	1.023270	106
1.021288	1.021570	1.021869	1.022151	1.022440	1.022769	1.023098	1.023464	1.023820	107
1.021782	1.022070	1.022376	1.022664	1.022960	1.023296	1.023632	1.024006	1.024370	108
1.022276	1.022570	1.022883	1.023177	1.023480	1.023823	1.024166	1.024548	1.024920	109
1.022770	1.023070	1.023390	1.023690	1.024000	1.024350	1.024700	1.025090	1.025470	110
1.023284	1.023590	1.023917	1.024224	1.024541	1.024899	1.025256	1.025654	1.026042	111
1.023798	1.024110	1.024444	1.024758	1.025082	1.025448	1.025812	1.026218	1.026614	112
1.024312	1.024630	1.024971	1.025292	1.025623	1.025997	1.026368	1.026782	1.027186	113
1.024826	1.025150	1.025498	1.025826	1.026164	1.026546	1.026924	1.027346	1.027758	114
1.025340	1.025670	1.026025	1.026360	1.026705	1.027095	1.027480	1.027910	1.028330	115
1.025854	1.026190	1.026552	1.026894	1.027246	1.027644	1.028036	1.028474	1.028902	116
1.026368	1.026710	1.027079	1.027428	1.027787	1.028193	1.028592	1.029038	1.029474	117
1.026882	1.027230	1.027606	1.027962	1.028328	1.028742	1.029148	1.029602	1.030046	118
1.027396	1.027750	1.028138	1.028496	1.028869	1.029291	1.029704	1.030166	1.030618	119
1.027910	1.028270	1.028660	1.029030	1.029410	1.029840	1.030260	1.030730	1.031190	120
1.028444	1.028811	1.029208	1.029585	1.029973	1.030411	1.030839	1.031317	1.031785	121
1.028978	1.029352	1.029756	1.030140	1.030536	1.030982	1.031418	1.031904	1.032380	122
1.029512	1.029893	1.030304	1.030695	1.031099	1.031553	1.031997	1.032491	1.032975	123
1.030046	1.030434	1.030852	1.031250	1.031662	1.032124	1.032576	1.033078	1.033570	124
1.030580	1.030975	1.031400	1.031805	1.032225	1.032695	1.033155	1.033665	1.034165	125
1.031114	1.031516	1.031948	1.032360	1.032788	1.033266	1.033734	1.034252	1.034760	126
1.031648	1.032057	1.032496	1.032915	1.033351	1.033837	1.034313	1.034839	1.035355	127
1.032182	1.032598	1.033044	1.033470	1.033914	1.034408	1.034892	1.035426	1.035950	128
1.032716	1.033139	1.033592	1.034025	1.034477	1.034979	1.035471	1.036013	1.036545	129
1.033250	1.033680	1.034140	1.034580	1.035040	1.035550	1.036050	1.036600	1.037140	130

TABLES FOR THE RAPID AND EXACT COMPUTATION OF THE NUMBER OF GALLONS CONTAINED IN ANY GIVEN WEIGHT OF OIL OR OTHER LIQUID LIGHTER THAN WATER, WITHOUT MEASURING OR GAUGING.

ARRANGED WITH SPECIAL REFERENCE TO THE WANTS OF THE PETROLEUM TRADE.

By S. A. Lattimore, A. M., *Professor of Chemistry in the University of Rochester, New York.*

Instructions for the use of the tables.—Ascertain the net weight of the oil or other fluid by the balance. The gravity is to be next accurately ascertained by means of a correct hydrometer, the temperature of the fluid being 60° F. and the line of the scale just below the surface being taken. Turn to the page on which that gravity is given. In the first column find the number of pounds. Opposite this number, in the column for the proper gravity, will be found the corresponding number of gallons, tenths and hundredths. If the exact number of pounds does not occur, take the nearest smaller number, then the number next less than the remainder, and so on, until the sum of these several numbers is the exact number of pounds required.

Example.

In 2,384 pounds of oil of 45° B., how many gallons?

	Gallons.
2,000 pounds	300.08
300 pounds	45.01
80 pounds	12.00
4 pounds	0.60
2,384 pounds	357.69

An additional series of tables is given embracing the more common gravities of petroleum products and the range of the number of gallons ordinarily contained in a single cask. Find the page for the required gravity, and opposite the net weight will be found the exact number of gallons contained in the cask.

DEGREES OF BAUMÉ'S HYDROMETER.

Pounds.	15°.	16°.	17°.	18°.	19°.	20°.	21°.	22°.	23°.	24°.	25°.	26°.	27°.	28°.
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
1	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14
2	0.25	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.26	0.27	0.27	0.27	0.27
3	0.37	0.38	0.38	0.38	0.38	0.39	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.41
4	0.50	0.50	0.50	0.51	0.51	0.52	0.52	0.52	0.53	0.53	0.53	0.54	0.54	0.54
5	0.62	0.63	0.63	0.63	0.64	0.64	0.65	0.65	0.66	0.66	0.66	0.67	0.67	0.68
6	0.75	0.76	0.76	0.76	0.77	0.77	0.78	0.78	0.79	0.79	0.80	0.80	0.81	0.81
7	0.87	0.88	0.88	0.89	0.89	0.90	0.91	0.91	0.92	0.92	0.93	0.94	0.94	0.95
8	1.00	1.00	1.01	1.02	1.02	1.03	1.04	1.04	1.05	1.06	1.06	1.07	1.08	1.08
9	1.12	1.13	1.13	1.14	1.15	1.16	1.17	1.17	1.18	1.20	1.20	1.20	1.21	1.22
10	1.24	1.25	1.26	1.27	1.28	1.29	1.30	1.30	1.31	1.32	1.33	1.34	1.35	1.35
20	2.49	2.50	2.52	2.54	2.56	2.57	2.58	2.61	2.62	2.64	2.66	2.68	2.69	2.71
30	3.73	3.76	3.78	3.81	3.83	3.86	3.88	3.91	3.94	3.96	3.99	4.01	4.04	4.06
40	4.97	5.01	5.04	5.08	5.11	5.15	5.18	5.21	5.25	5.28	5.31	5.35	5.38	5.42
50	6.22	6.26	6.30	6.34	6.39	6.43	6.47	6.52	6.56	6.60	6.64	6.69	6.73	6.77
60	7.46	7.51	7.56	7.61	7.67	7.72	7.77	7.82	7.87	7.92	7.97	8.03	8.08	8.13
70	8.70	8.76	8.82	8.88	8.94	9.00	9.06	9.12	9.18	9.24	9.30	9.36	9.42	9.48
80	9.95	10.01	10.08	10.15	10.22	10.29	10.36	10.43	10.49	10.56	10.63	10.70	10.77	10.84
90	11.19	11.27	11.34	11.42	11.50	11.58	11.65	11.73	11.81	11.98	11.96	12.04	12.12	12.19
100	12.43	12.52	12.61	12.69	12.78	12.86	12.95	13.03	13.12	13.21	13.29	13.38	13.46	13.55
200	24.87	25.04	25.21	25.38	25.55	25.72	25.84	26.07	26.24	26.41	26.57	26.75	26.92	27.10
300	37.30	37.55	37.81	38.07	38.33	38.58	38.84	39.10	39.36	39.62	39.86	40.13	40.38	40.64
400	49.73	50.07	50.42	50.76	51.11	51.45	51.79	52.13	52.47	52.82	53.15	53.50	53.85	54.19
500	62.16	62.59	63.02	63.45	63.88	64.31	64.74	65.16	65.59	66.03	66.45	66.88	67.30	67.74
1,000	124.32	125.18	126.05	126.90	127.76	128.61	129.47	130.33	131.18	132.05	132.87	133.76	134.61	135.48
2,000	248.65	250.36	252.09	253.80	255.53	257.22	258.94	260.66	262.37	264.10	265.73	267.52	269.22	270.96
3,000	372.97	375.54	378.13	380.69	383.29	385.84	388.42	390.99	393.55	396.15	398.60	401.28	403.83	406.43
4,000	497.29	500.71	504.18	507.59	511.05	514.45	517.89	521.31	524.73	528.20	531.47	535.03	538.45	541.91
5,000	621.61	625.89	630.23	634.49	638.81	643.06	647.36	651.64	655.92	660.25	664.34	668.79	673.06	677.39
10,000	1,243.22	1,251.78	1,260.46	1,268.99	1,277.63	1,286.12	1,294.72	1,303.29	1,311.84	1,320.50	1,328.67	1.337.58	1,346.11	1,354.78
20,000	2,486.45	2,503.57	2,520.92	2,537.97	2,555.26	2,572.24	2,589.43	2,606.58	2,623.67	2,641.00	2,657.35	2,675.15	2,692.22	2,709.56

DEGREES OF BAUMÉ'S HYDROMETER—Continued.

Pounds.	29°.	30°.	31°.	32°.	33°.	34°.	35°.	36°.	37°.	38°.	39°.	40°.	41°.	42°.
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
1	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15
2	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.29	0.29
3	0.41	0.41	0.41	0.42	0.42	0.42	0.43	0.43	0.43	0.43	0.43	0.44	0.44	0.44
4	0.55	0.55	0.56	0.56	0.56	0.56	0.57	0.57	0.57	0.58	0.58	0.58	0.59	0.59
5	0.68	0.69	0.69	0.69	0.70	0.70	0.71	0.71	0.72	0.72	0.72	0.73	0.73	0.74
6	0.82	0.82	0.83	0.83	0.84	0.84	0.85	0.85	0.86	0.86	0.87	0.88	0.88	0.89
7	0.95	0.96	0.97	0.97	0.98	0.98	0.99	1.00	1.00	1.01	1.01	1.02	1.03	1.03
8	1.09	1.10	1.10	1.11	1.12	1.13	1.13	1.14	1.15	1.15	1.16	1.17	1.17	1.18
9	1.23	1.24	1.24	1.25	1.26	1.27	1.27	1.28	1.29	1.30	1.30	1.30	1.32	1.33
10	1.36	1.37	1.38	1.39	1.40	1.40	1.41	1.42	1.43	1.44	1.45	1.46	1.47	1.47
20	2.73	2.74	2.76	2.78	2.80	2.81	2.83	2.85	2.87	2.88	2.90	2.92	2.93	2.95
30	4.09	4.12	4.14	4.17	4.19	4.22	4.25	4.27	4.30	4.32	4.35	4.37	4.40	4.42
40	5.45	5.49	5.52	5.56	5.59	5.63	5.66	5.69	5.73	5.76	5.80	5.83	5.86	5.90
50	6.82	6.86	6.90	6.94	6.99	7.03	7.07	7.12	7.16	7.20	7.24	7.29	7.33	7.37
60	8.18	8.23	8.28	8.33	8.39	8.44	8.49	8.54	8.60	8.64	8.69	8.75	8.80	8.85
70	9.53	9.60	9.66	9.72	9.78	9.84	9.91	9.96	10.03	10.08	10.14	10.20	10.26	10.32
80	10.91	10.97	11.04	11.11	11.18	11.25	11.33	11.39	11.46	11.52	11.59	11.66	11.73	11.80
90	12.27	12.35	12.42	12.50	12.58	12.66	12.73	12.81	12.89	12.96	13.04	13.12	13.20	13.27
100	13.63	13.72	13.80	13.89	13.98	14.06	14.15	14.23	14.33	14.40	14.49	14.58	14.66	14.75
200	27.27	27.44	27.61	27.78	27.95	28.12	28.30	28.47	28.65	28.81	28.98	29.16	29.32	29.50
300	40.90	41.15	41.42	41.67	41.93	42.19	42.45	42.70	42.98	43.21	43.46	43.73	43.98	44.24
400	54.53	54.87	55.22	55.56	55.91	56.25	56.60	56.93	57.30	57.62	57.95	58.31	58.65	58.99
500	68.16	68.59	69.02	69.45	69.88	70.31	70.74	71.17	71.63	72.02	72.44	72.89	72.31	73.74
1,000	136.33	137.18	138.05	138.91	139.77	140.62	141.48	142.34	143.26	144.04	144.88	145.77	146.61	147.48
2,000	272.65	274.36	276.10	277.81	279.54	281.24	282.97	284.67	286.51	288.09	289.76	291.55	293.23	294.96
3,000	408.97	411.54	414.14	416.71	419.30	421.87	424.44	427.02	429.78	432.12	434.64	437.31	439.84	442.44
4,000	545.30	548.72	552.19	555.62	559.07	562.49	565.92	569.36	573.04	576.16	579.52	583.09	586.46	589.92
5,000	681.63	685.90	690.24	694.52	698.84	703.11	707.41	711.68	716.29	720.24	724.41	728.86	733.07	737.40
10,000	1,363.25	1,371.81	1,380.49	1,389.05	1,397.68	1,406.21	1,414.83	1,423.36	1,432.58	1,440.47	1,448.81	1,457.73	1,466.15	1,474.80
20,000	2,726.50	2,743.63	2,760.98	2,778.10	2,795.36	2,812.42	2,829.65	2,846.73	2,865.16	2,880.93	2,897.63	2,915.45	2,932.29	2,949.59

Pounds.	43°.	44°.	45°.	46°.	47°.	48°.	49°.	50°.	51°.	52°.	53°.	54°.	55°.	56°.
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16
2	0.30	0.30	0.30	0.30	0.30	0.31	0.31	0.31	0.31	0.31	0.31	0.32	0.32	0.32
3	0.45	0.45	0.45	0.45	0.46	0.46	0.46	0.46	0.47	0.47	0.47	0.47	0.48	0.48
4	0.59	0.60	0.60	0.60	0.61	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.64	0.64
5	0.74	0.75	0.75	0.76	0.76	0.76	0.77	0.77	0.78	0.78	0.79	0.79	0.79	0.80
6	0.89	0.89	0.90	0.91	0.91	0.92	0.92	0.93	0.93	0.94	0.94	0.95	0.95	0.96
7	1.04	1.04	1.05	1.06	1.06	1.07	1.07	1.08	1.09	1.09	1.10	1.10	1.11	1.12
8	1.19	1.19	1.20	1.21	1.21	1.22	1.23	1.24	1.24	1.25	1.26	1.26	1.27	1.28
9	1.34	1.34	1.35	1.36	1.37	1.37	1.38	1.39	1.40	1.40	1.41	1.42	1.43	1.44
10	1.48	1.49	1.50	1.51	1.52	1.53	1.53	1.54	1.55	1.56	1.57	1.58	1.59	1.59
20	2.97	2.98	3.00	3.02	3.04	3.05	3.07	3.09	3.10	3.12	3.14	3.16	3.17	3.19
30	4.45	4.47	4.50	4.53	4.55	4.58	4.60	4.63	4.66	4.68	4.71	4.73	4.76	4.78
40	5.93	5.96	6.00	6.04	6.07	6.11	6.14	6.17	6.21	6.24	6.28	6.31	6.35	6.38
50	7.41	7.45	7.50	7.55	7.59	7.63	7.67	7.72	7.76	7.80	7.85	7.89	7.93	7.97
60	8.90	8.94	9.00	9.05	9.11	9.16	9.21	9.26	9.31	9.36	9.41	9.47	9.52	9.57
70	10.38	10.43	10.50	10.56	10.62	10.68	10.74	10.80	10.86	10.92	10.98	11.04	11.10	11.16
80	11.87	11.92	12.00	12.07	12.14	12.21	12.28	12.35	12.42	12.48	12.55	12.62	12.69	12.76
90	13.35	13.41	13.50	13.59	13.66	13.74	13.81	13.89	13.97	14.04	14.12	14.20	14.28	14.35
100	14.83	14.91	15.00	15.09	15.18	15.26	15.35	15.43	15.52	15.61	15.69	15.78	15.86	15.95
200	29.67	29.81	30.00	30.18	30.36	30.52	30.70	30.87	31.04	31.21	31.38	31.56	31.73	31.90
300	44.50	44.72	45.01	45.27	45.53	45.79	46.04	46.30	46.56	46.82	47.07	47.33	47.59	47.85
400	59.34	59.62	60.02	60.36	60.71	61.05	61.39	61.74	62.08	62.42	62.76	63.11	63.45	63.80
500	74.17	74.53	75.02	75.45	75.88	76.31	76.74	77.17	77.60	78.03	78.45	78.89	79.31	79.75
1,000	148.34	149.05	150.04	150.91	151.77	152.62	163.48	154.34	155.20	156.05	156.91	157.77	158.63	159.49
2,000	296.67	298.11	300.08	301.82	303.56	305.24	306.95	308.69	310.40	312.10	313.81	315.55	317.25	318.98
3,000	445.02	447.16	450.13	452.73	455.30	457.85	460.43	463.03	465.60	468.15	470.72	473.32	475.88	478.47
4,000	593.35	596.22	600.17	603.64	607.07	610.47	613.91	617.38	620.80	624.20	627.63	631.09	634.51	637.96
5,000	741.69	745.27	750.21	754.55	758.84	763.09	767.38	771.72	776.01	780.25	784.54	788.87	793.13	797.45
10,000	1,483.37	1,490.53	1,500.42	1,509.09	1,517.68	1,526.18	1,534.75	1,543.45	1,552.02	1,560.50	1,569.07	1,577.74	1,586.27	1,594.90
20,000	2,966.74	2,981.67	3,000.84	3,018.18	3,035.56	3,052.36	3,069.51	3,086.90	3,104.05	3,121.00	3,138.14	3,155.47	3,172.53	3,189.70

DEGREES OF BAUMÉ'S HYDROMETER—Continued.

Pounds.	57°.	58°.	59°.	60°.	61°.	62°.	63°.	64°.	65°.	70°.	75°.	80°.	85°.
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
1	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.18
2	0.32	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.33	0.34	0.35	0.36	0.37
3	0.48	0.48	0.49	0.49	0.49	0.49	0.50	0.50	0.50	0.51	0.53	0.54	0.55
4	0.64	0.65	0.65	0.65	0.66	0.66	0.66	0.67	0.67	0.69	0.70	0.72	0.74
5	0.80	0.81	0.81	0.82	0.82	0.82	0.83	0.83	0.84	0.86	0.88	0.99	0.92
6	0.96	0.97	0.97	0.98	0.98	0.99	1.00	1.00	1.00	1.03	1.06	1.08	1.11
7	1.12	1.13	1.13	1.14	1.15	1.15	1.16	1.16	1.17	1.20	1.23	1.26	1.29
8	1.28	1.29	1.30	1.30	1.31	1.31	1.32	1.33	1.34	1.37	1.41	1.44	1.48
9	1.44	1.45	1.46	1.47	1.47	1.48	1.49	1.50	1.50	1.54	1.58	1.62	1.66
10	1.60	1.61	1.62	1.63	1.64	1.65	1.65	1.66	1.67	1.72	1.76	1.80	1.84
20	3.21	3.22	3.24	3.24	3.28	3.29	3.31	3.33	3.34	3.43	3.52	3.60	3.69
30	4.81	4.84	4.86	4.89	4.91	4.94	4.96	4.99	5.02	5.14	5.28	5.40	5.53
40	6.41	6.45	6.48	6.52	6.55	6.59	6.62	6.65	6.69	6.86	7.03	7.20	7.37
50	8.02	8.06	8.10	8.15	8.19	8.23	8.27	8.32	8.36	8.57	8.79	9.00	9.22
60	9.62	9.67	9.72	9.77	9.83	9.88	9.93	9.99	10.03	10.29	10.55	10.80	11.06
70	11.22	11.28	11.34	11.40	11.46	11.53	11.58	11.64	11.69	12.00	12.31	12.60	12.90
80	12.83	12.90	12.96	13.03	13.10	13.16	13.24	13.31	13.38	13.72	14.07	14.41	14.75
90	14.43	14.51	14.58	14.66	14.74	14.82	14.89	14.97	15.05	15.43	15.83	16.21	16.59
100	16.03	16.12	16.21	16.29	16.38	16.47	16.55	16.64	16.72	17.15	17.59	18.01	18.44
200	32.07	32.24	32.41	32.58	32.76	32.93	33.10	33.27	33.44	34.30	35.17	36.01	36.87
300	48.10	48.36	48.61	48.87	49.13	49.40	49.65	49.90	50.16	51.44	52.76	54.02	55.31
400	64.14	64.48	64.82	65.16	65.51	65.86	66.20	66.54	66.88	68.59	70.34	72.03	73.74
500	80.17	80.60	81.03	81.46	81.89	82.33	82.75	83.17	83.60	85.74	87.93	90.04	92.18
1,000	160.34	161.21	162.05	162.91	163.78	164.66	165.49	166.35	167.20	171.48	175.86	180.07	184.36
2,000	320.69	322.41	324.11	323.82	327.56	329.31	330.99	332.69	334.40	342.95	351.72	360.14	368.71
3,000	481.03	483.60	486.16	488.73	491.34	493.97	496.48	499.03	510.60	514.43	527.58	540.21	553.06
4,000	641.37	644.82	648.21	651.64	655.11	658.62	661.98	665.38	668.81	685.91	703.44	720.28	737.42
5,000	801.72	806.02	810.27	814.56	818.89	823.28	827.47	831.73	836.01	857.38	879.30	900.35	921.77
10,000	1,603.44	1,612.05	1,620.54	1,629.12	1,637.79	1,646.55	1,654.94	1,663.45	1,672.02	1,714.77	1,758.59	1,800.70	1,843.55
20,000	3,206.87	3,224.09	3,241.07	3,238.24	3,275.57	3,293.10	3,309.88	3,326.90	3,344.03	3,429.53	3,517.18	3,601.40	3,687.11

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL.

15° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
288	35.8	318	39.5	348	43.3	378	47.0	408	50.7
289	35.9	319	39.7	349	43.4	379	47.1	409	50.9
290	36.1	320	39.8	350	43.5	380	47.3	410	51.0
291	36.2	321	39.9	351	43.6	381	47.4	411	51.1
292	36.3	322	40.0	352	43.8	382	47.5	412	51.2
293	36.4	323	40.2	353	43.9	383	47.6	413	51.3
294	36.6	324	40.3	354	44.0	384	47.8	414	51.5
295	36.7	325	40.4	355	44.1	385	47.9	415	51.6
296	36.8	326	40.5	356	44.3	386	48.0	416	51.7
297	36.9	327	40.7	357	44.4	387	48.1	417	51.8
298	37.1	328	40.8	358	44.5	388	48.3	418	52.0
299	37.2	329	40.9	359	44.6	389	48.4	419	52.1
300	37.3	330	41.0	360	44.8	390	48.5	420	52.2
301	37.4	331	41.2	361	44.9	391	48.6	421	52.3
302	37.6	332	41.3	362	45.0	392	48.7	422	52.5
303	37.7	333	41.4	363	45.1	393	48.9	423	52.6
304	37.8	334	41.5	364	45.3	394	49.0	424	52.7
305	37.9	335	41.7	365	45.4	395	49.1	425	52.8
306	38.1	336	41.8	366	45.5	396	49.2	426	53.0
307	38.2	337	41.9	367	45.6	397	49.4	427	53.1
308	38.3	338	42.0	368	45.8	398	49.5	428	53.2
309	38.4	339	42.2	369	45.9	399	49.6	429	53.3
310	38.5	340	42.3	370	46.0	400	49.7	430	53.5
311	38.7	341	42.4	371	46.1	401	49.9	431	53.6
312	38.8	342	42.5	372	46.3	402	50.0	432	53.7
313	38.9	343	42.6	373	46.4	403	50.1	433	53.8
314	39.0	344	42.8	374	46.5	404	50.2	434	53.9
315	39.2	345	42.9	375	46.6	405	50.4	435	54.0
316	39.3	346	43.0	376	46.8	406	50.5	436	54.2
317	39.4	347	43.1	377	46.9	407	50.6	437	54.3

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

20° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
280	36.0	310	39.9	340	43.7	370	47.6	400	51.5
281	36.1	311	40.0	341	43.9	371	47.7	401	51.6
282	36.3	312	40.1	342	44.0	372	47.8	402	51.7
283	36.4	313	40.3	343	44.1	373	48.0	403	51.8
284	36.5	314	40.4	344	44.3	374	48.1	404	52.0
285	36.7	315	40.5	345	44.4	375	48.2	405	52.1
286	36.8	316	40.6	346	44.5	376	48.4	406	52.2
287	36.9	317	40.8	347	44.6	377	48.5	407	52.4
288	37.0	318	40.9	348	44.8	378	48.6	408	52.5
289	37.2	319	41.0	349	44.9	379	48.7	409	52.6
290	37.3	320	41.2	350	45.0	380	48.9	410	52.7
291	37.4	321	41.3	351	45.1	381	49.0	411	52.9
292	37.6	322	41.4	352	45.3	382	49.1	412	53.0
293	37.7	323	41.5	353	45.4	383	49.3	413	53.1
294	37.8	324	41.7	354	45.5	384	49.4	414	53.3
295	37.9	325	41.8	355	45.7	385	49.5	415	53.4
296	38.1	326	41.9	356	45.8	386	49.6	416	53.5
297	38.2	327	42.1	357	45.9	387	49.8	417	53.6
298	38.3	328	42.2	358	46.0	388	49.9	418	53.8
299	38.5	329	42.3	359	46.2	389	50.0	419	53.9
300	38.6	330	42.4	360	46.3	390	50.2	420	54.0
301	38.7	331	42.6	361	46.4	391	50.3	421	54.2
302	38.8	332	42.7	362	46.6	392	50.4	422	54.3
303	39.0	333	42.8	363	46.7	393	50.6	423	54.4
304	39.1	334	43.0	364	46.8	394	50.7	424	54.5
305	39.2	335	43.1	365	46.9	395	50.8	425	54.7
306	39.4	336	43.2	366	47.1	396	50.9	426	54.8
307	39.5	337	43.3	367	47.2	397	51.1	427	54.9
308	39.6	338	43.5	368	47.3	398	51.2	428	55.1
309	39.7	339	43.6	369	47.5	399	51.3	429	55.2

21° GRAVITY.

278	35.9	308	39.9	338	43.8	368	47.7	398	51.5
279	36.1	309	40.0	339	43.9	369	47.8	399	51.7
280	36.2	310	40.1	340	44.0	370	47.9	400	51.8
281	36.3	311	40.3	341	44.2	371	48.0	401	51.9
282	36.5	312	40.4	342	44.3	372	48.2	402	52.1
283	36.6	313	40.5	343	44.4	373	48.3	403	52.2
284	36.7	314	40.7	344	44.5	374	48.4	404	52.3
285	36.9	315	40.8	345	44.7	375	48.6	405	52.4
286	37.0	316	40.9	346	44.8	376	48.7	406	52.6
287	37.1	317	41.1	347	44.9	377	48.8	407	52.7
288	37.2	318	41.2	348	45.1	378	48.9	408	52.8
289	37.4	319	41.3	349	45.2	379	49.1	409	53.0
290	37.5	320	41.4	350	45.3	380	49.2	410	53.1
291	37.6	321	41.6	351	45.4	381	49.3	411	53.2
292	37.8	322	41.7	352	45.6	382	49.5	412	53.4
293	37.9	323	41.8	353	45.7	383	49.6	413	53.5
294	38.0	324	41.9	354	45.8	384	49.7	414	53.6
295	38.1	325	42.1	355	46.0	385	49.9	415	53.7
296	38.3	326	42.2	356	46.1	386	50.0	416	53.9
297	38.4	327	42.3	357	46.2	387	50.1	417	54.0
298	38.5	328	42.5	358	46.4	388	50.2	418	54.1
299	38.7	329	42.6	359	46.5	389	50.4	419	54.3
300	38.8	330	42.7	360	46.6	390	50.5	420	54.4
301	39.0	331	42.9	361	46.7	391	50.6	421	54.5
302	39.1	332	43.0	362	46.9	392	50.8	422	54.6
303	39.2	333	43.1	363	47.0	393	50.9	423	54.8
304	39.4	334	43.2	364	47.1	394	51.0	424	54.9
305	39.5	335	43.4	365	47.3	395	51.1	425	55.0
306	39.6	336	43.5	366	47.4	396	51.3	426	55.2
307	39.8	337	43.6	367	47.5	397	51.4	427	55.3

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

22° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
275	35.8	305	39.8	335	43.7	365	47.6	395	51.5
276	36.0	306	39.9	336	43.8	366	47.7	396	51.6
277	36.1	307	40.0	337	43.9	367	47.8	397	51.7
278	36.2	308	40.1	338	44.1	368	48.0	398	51.9
279	36.4	309	40.3	339	44.2	369	48.1	399	52.0
280	36.5	310	40.4	340	44.3	370	48.2	400	52.1
281	36.6	311	40.5	341	44.4	371	48.4	401	52.3
282	36.8	312	40.7	342	44.6	372	48.5	402	52.4
283	36.9	313	40.8	343	44.7	373	48.6	403	52.5
284	37.0	314	40.9	344	44.8	374	48.7	404	52.7
285	37.2	315	41.1	345	45.0	375	48.9	405	52.8
286	37.3	316	41.2	346	45.1	376	49.0	406	52.9
287	37.4	317	41.3	347	45.2	377	49.1	407	53.0
288	37.5	318	41.4	348	45.4	378	49.3	408	53.2
289	37.7	319	41.6	349	45.5	379	49.4	409	53.3
290	37.8	320	41.7	350	45.6	380	49.5	410	53.4
291	37.9	321	41.8	351	45.8	381	49.7	411	53.6
292	38.1	322	42.0	352	45.9	382	49.8	412	53.7
293	38.2	323	42.1	353	46.0	383	49.9	413	53.8
294	38.3	324	42.2	354	46.1	384	50.1	414	54.0
295	38.5	325	42.4	355	46.3	385	50.2	415	54.1
296	38.6	326	42.5	356	46.4	386	50.3	416	54.2
297	38.7	327	42.6	357	46.5	387	50.4	417	54.3
298	38.8	328	42.8	358	46.7	388	50.6	418	54.5
299	39.0	329	42.9	359	46.8	389	50.7	419	54.6
300	39.1	330	43.0	360	46.9	390	50.8	420	54.7
301	39.2	331	43.1	361	47.1	391	51.0	421	54.9
302	39.4	332	43.3	362	47.2	392	51.1	422	55.0
303	39.5	333	43.4	363	47.3	393	51.2	423	55.1
304	39.6	334	43.5	364	47.4	394	51.4	424	55.3

23° GRAVITY.

274	36.0	304	39.9	334	43.8	364	47.8	394	51.7
275	36.1	305	40.0	335	44.0	365	47.9	395	51.8
276	36.2	306	40.2	336	44.1	366	48.0	396	52.0
277	36.3	307	40.3	337	44.2	367	48.2	397	52.1
278	36.5	308	40.4	338	44.4	368	48.3	398	52.2
279	36.6	309	40.5	339	44.5	369	48.4	399	52.4
280	36.7	310	40.7	340	44.6	370	48.5	400	52.5
281	36.9	311	40.8	341	44.7	371	48.7	401	52.6
282	37.0	312	40.9	342	44.9	372	48.8	402	52.7
283	37.1	313	41.1	343	45.0	373	48.9	403	52.9
284	37.3	314	41.2	344	45.1	374	49.1	404	53.0
285	37.4	315	41.3	345	45.3	375	49.2	405	53.1
286	37.5	316	41.5	346	45.4	376	49.3	406	53.3
287	37.7	317	41.6	347	45.5	377	49.5	407	53.4
288	37.8	318	41.7	348	45.7	378	49.6	408	53.5
289	37.9	319	41.9	349	45.8	379	49.7	409	53.7
290	38.1	320	42.0	350	45.9	380	49.9	410	53.8
291	38.2	321	42.1	351	46.1	381	50.0	411	53.9
292	38.3	322	42.2	352	46.2	382	50.1	412	54.1
293	38.4	323	42.4	353	46.3	383	50.2	413	54.2
294	38.6	324	42.5	354	46.5	384	50.4	414	54.3
295	38.7	325	42.6	355	46.6	385	50.5	415	54.4
296	38.8	326	42.8	356	46.7	386	50.6	416	54.6
297	39.0	327	42.9	357	46.8	387	50.8	417	54.7
298	39.1	328	43.0	358	47.0	388	50.9	418	54.8
299	39.2	329	43.2	359	47.1	389	51.0	419	55.0
300	39.4	330	43.3	360	47.2	390	51.2	420	55.1
301	39.5	331	43.4	361	47.4	391	51.3	421	55.2
302	39.6	332	43.6	362	47.5	392	51.4	422	55.4
303	39.8	333	43.7	363	47.6	393	51.6	423	55.5

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

24° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
272	35.9	302	39.9	332	43.8	362	47.8	392	51.8
273	36.1	303	40.0	333	44.0	363	47.9	393	51.9
274	36.2	304	40.2	334	44.1	364	48.1	394	52.0
275	36.3	305	40.3	335	44.2	365	48.2	395	52.2
276	36.4	306	40.4	336	44.4	366	48.3	396	52.3
277	36.6	307	40.5	337	44.5	367	48.5	397	52.4
278	36.7	308	40.7	338	44.6	368	48.6	398	52.6
279	36.9	309	40.8	339	44.8	369	48.7	399	52.7
280	37.0	310	40.9	340	44.9	370	48.9	400	52.8
281	37.1	311	41.1	341	45.0	371	49.0	401	53.0
282	37.2	312	41.2	342	45.2	372	49.1	402	53.1
283	37.4	313	41.3	343	45.3	373	49.3	403	53.2
284	37.5	314	41.5	344	45.4	374	49.4	404	53.4
285	37.6	315	41.6	345	45.6	375	49.5	405	53.5
286	37.8	316	41.7	346	45.7	376	49.7	406	53.6
287	37.9	317	41.9	347	45.8	377	49.8	407	53.7
288	38.0	318	42.0	348	46.0	378	49.9	408	53.9
289	38.2	319	42.1	349	46.1	379	50.1	409	54.0
290	38.3	320	42.3	350	46.2	380	50.2	410	54.1
291	38.4	321	42.4	351	46.4	381	50.3	411	54.3
292	38.6	322	42.5	352	46.5	382	50.4	412	54.4
293	38.7	323	42.7	353	46.6	383	50.6	413	54.5
294	38.8	324	42.8	354	46.8	384	50.7	414	54.7
295	39.0	325	42.9	355	46.9	385	50.8	415	54.8
296	39.1	326	43.1	356	47.0	386	51.0	416	54.9
297	39.2	327	43.2	357	47.1	387	51.1	417	55.1
298	39.4	328	43.3	358	47.3	388	51.2	418	55.2
299	39.5	329	43.5	359	47.4	389	51.4	419	55.3
300	39.6	330	43.6	360	47.5	390	51.5	420	55.5
301	39.8	331	43.7	361	47.7	391	51.6	421	55.6

25° GRAVITY.

271	36.0	301	40.0	331	44.0	361	48.0	391	52.0
272	36.1	302	40.1	332	44.1	362	48.1	392	52.1
273	36.3	303	40.3	333	44.3	363	48.2	393	52.2
274	36.4	304	40.4	334	44.4	364	48.4	394	52.4
275	36.5	305	40.5	335	44.5	365	48.5	395	52.5
276	36.7	306	40.7	336	44.7	366	48.6	396	52.6
277	36.8	307	40.8	337	44.8	367	48.8	397	52.8
278	36.9	308	40.9	338	44.9	368	48.9	398	52.9
279	37.1	309	41.1	339	45.1	369	49.0	399	53.0
280	37.2	310	41.2	340	45.2	370	49.2	400	53.2
281	37.3	311	41.3	341	45.3	371	49.3	401	53.3
282	37.5	312	41.5	342	45.4	372	49.4	402	53.4
283	37.6	313	41.6	343	45.6	373	49.6	403	53.6
284	37.7	314	41.7	344	45.7	374	49.7	404	53.7
285	37.9	315	41.9	345	45.8	375	49.8	405	53.8
286	38.0	316	42.0	346	46.0	376	50.0	406	54.0
287	38.1	317	42.1	347	46.1	377	50.1	407	54.1
288	38.3	318	42.3	348	46.2	378	50.2	408	54.2
289	38.4	319	42.4	349	46.4	379	50.4	409	54.4
290	38.5	320	42.5	350	46.5	380	50.5	410	54.5
291	38.7	321	42.7	351	46.6	381	50.6	411	54.6
292	38.8	322	42.8	352	46.8	382	50.8	412	54.8
293	38.9	323	42.9	353	46.9	383	50.9	413	54.9
294	39.1	324	43.1	354	47.0	384	51.0	414	55.0
295	39.2	325	43.2	355	47.2	385	51.2	415	55.1
296	39.3	326	43.3	356	47.3	386	51.3	416	55.3
297	39.5	327	43.5	357	47.4	387	51.4	417	55.4
298	39.6	328	43.6	358	47.6	388	51.6	418	55.5
299	39.7	329	43.7	359	47.7	389	51.7	419	55.7
300	39.9	330	43.9	360	47.8	390	51.8	420	55.8

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

26° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
269	36.0	299	40.0	329	44.0	359	48.0	389	52.0
270	36.1	300	40.1	330	44.1	360	48.2	390	52.2
271	36.2	301	40.3	331	44.3	361	48.3	391	52.3
272	36.4	302	40.4	332	44.4	362	48.4	392	52.4
273	36.5	303	40.5	333	44.5	363	48.6	393	52.6
274	36.7	304	40.7	334	44.7	364	48.7	394	52.7
275	36.8	305	40.8	335	44.8	365	48.8	395	52.8
276	36.9	306	40.9	336	44.9	366	49.0	396	53.0
277	37.1	307	41.1	337	45.1	367	49.1	397	53.1
278	37.2	308	41.2	338	45.2	368	49.2	398	53.2
279	37.3	309	41.3	339	45.3	369	49.4	399	53.4
280	37.5	310	41.5	340	45.5	370	49.5	400	53.5
281	37.6	311	41.6	341	45.6	371	49.6	401	53.6
282	37.7	312	41.7	342	45.8	372	49.8	402	53.8
283	37.9	313	41.9	343	45.9	373	49.9	403	53.9
284	38.0	314	42.0	344	46.0	374	50.0	404	54.0
285	38.1	315	42.1	345	46.2	375	50.2	405	54.2
286	38.3	316	42.3	346	46.3	376	50.3	406	54.3
287	38.4	317	42.4	347	46.4	377	50.4	407	54.4
288	38.5	318	42.5	348	46.6	378	50.6	408	54.6
289	38.7	319	42.7	349	46.7	379	50.7	409	54.7
290	38.8	320	42.8	350	46.8	380	50.8	410	54.8
291	38.9	321	42.9	351	47.0	381	51.0	411	55.0
292	39.1	322	43.1	352	47.1	382	51.1	412	55.1
293	39.2	323	43.2	353	47.2	383	51.2	413	55.2
294	39.3	324	43.4	354	47.4	384	51.4	414	55.4
295	39.5	325	43.5	355	47.5	385	51.5	415	55.5
296	39.6	326	43.6	356	47.6	386	51.6	416	55.6
297	39.7	327	43.8	357	47.8	387	51.8	417	55.8
298	39.9	328	43.9	358	47.9	388	51.9	418	55.9

27° GRAVITY.

267	35.9	297	40.0	327	44.0	357	48.1	387	52.1
268	36.1	298	40.1	328	44.2	358	48.2	388	52.2
269	36.2	299	40.3	329	44.3	359	48.3	389	52.4
270	36.3	300	40.4	330	44.4	360	48.5	390	52.5
271	36.5	301	40.5	331	44.6	361	48.6	391	52.6
272	36.6	302	40.7	332	44.7	362	48.7	392	52.8
273	36.7	303	40.8	333	44.8	363	48.9	393	52.9
274	36.9	304	40.9	334	45.0	364	49.0	394	53.0
275	37.0	305	41.1	335	45.1	365	49.1	395	53.2
276	37.2	306	41.2	336	45.2	366	49.3	396	53.3
277	37.3	307	41.3	337	45.4	367	49.4	397	53.4
278	37.4	308	41.5	338	45.5	368	49.5	398	53.6
279	37.6	309	41.6	339	45.6	369	49.7	399	53.7
280	37.7	310	41.7	340	45.8	370	49.8	400	53.9
281	37.8	311	41.9	341	45.9	371	49.9	401	54.0
282	38.0	312	42.0	342	46.0	372	50.1	402	54.1
283	38.1	313	42.1	343	46.2	373	50.2	403	54.3
284	38.2	314	42.3	344	46.3	374	50.3	404	54.4
285	38.4	315	42.4	345	46.4	375	50.5	405	54.5
286	38.5	316	42.5	346	46.6	376	50.6	406	54.7
287	38.6	317	42.7	347	46.7	377	50.7	407	54.8
288	38.8	318	42.8	348	46.8	378	50.9	408	54.9
289	38.9	319	42.9	349	47.0	379	51.0	409	55.1
290	39.0	320	43.1	350	47.1	380	51.2	410	55.2
291	39.2	321	43.2	351	47.3	381	51.3	411	55.3
292	39.3	322	43.3	352	47.4	382	51.4	412	55.5
293	39.4	323	43.5	353	47.5	383	51.6	413	55.6
294	39.6	324	43.6	354	47.7	384	51.7	414	55.7
295	39.7	325	43.7	355	47.8	385	51.8	415	55.9
296	39.9	326	43.9	356	47.9	386	52.0	416	56.0

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

28° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
265	35.9	295	40.0	325	44.0	355	48.1	385	52.1
266	36.0	296	40.1	326	44.2	356	48.2	386	52.3
267	36.2	297	40.2	327	44.3	357	48.4	387	52.4
268	36.3	298	40.4	328	44.4	358	48.5	388	52.6
269	36.5	299	40.5	329	44.6	359	48.6	389	52.7
270	36.6	300	40.6	330	44.7	360	48.8	390	52.8
271	36.7	301	40.8	331	44.8	361	48.9	391	53.0
272	36.9	302	40.9	332	45.0	362	49.0	392	53.1
273	37.0	303	41.1	333	45.1	363	49.2	393	53.2
274	37.1	304	41.2	334	45.2	364	49.3	394	53.4
275	37.3	305	41.3	335	45.4	365	49.5	395	53.5
276	37.4	306	41.5	336	45.5	366	49.6	396	53.6
277	37.5	307	41.6	337	45.7	367	49.7	397	53.8
278	37.7	308	41.7	338	45.8	368	49.9	398	53.9
279	37.8	309	41.9	339	45.9	369	50.0	399	54.1
280	37.9	310	42.0	340	46.1	370	50.1	400	54.2
281	38.1	311	42.1	341	46.2	371	50.3	401	54.3
282	38.2	312	42.3	342	46.3	372	50.4	402	54.5
283	38.4	313	42.4	343	46.5	373	50.5	403	54.6
284	38.5	314	42.5	344	46.6	374	50.7	404	54.7
285	38.6	315	42.7	345	46.7	375	50.8	405	54.9
286	38.8	316	42.8	346	46.9	376	50.9	406	55.0
287	38.9	317	42.9	347	47.0	377	51.1	407	55.1
288	39.0	318	43.1	348	47.1	378	51.2	408	55.3
289	39.2	319	43.2	349	47.3	379	51.3	409	55.4
290	39.3	320	43.4	350	47.4	380	51.5	410	55.5
291	39.4	321	43.5	351	47.6	381	51.6	411	55.7
292	39.6	322	43.6	352	47.7	382	51.8	412	55.8
293	39.7	323	43.8	353	47.8	383	51.9	413	56.0
294	39.8	324	43.9	354	48.0	384	52.0	414	56.1

29° GRAVITY.

263	35.9	293	40.0	323	44.0	353	48.1	383	52.2
264	36.0	294	40.1	324	44.2	354	48.3	384	52.4
265	36.1	295	40.2	325	44.3	355	48.4	385	52.5
266	36.3	296	40.4	326	44.5	356	48.5	386	52.6
267	36.4	297	40.5	327	44.6	357	48.7	387	52.8
268	36.5	298	40.6	328	44.7	358	48.8	388	52.9
269	36.7	299	40.8	329	44.9	359	49.0	389	53.0
270	36.8	300	40.9	330	45.0	360	49.1	390	53.2
271	36.9	301	41.0	331	45.1	361	49.2	391	53.3
272	37.1	302	41.2	332	45.3	362	49.4	392	53.4
273	37.2	303	41.3	333	45.4	363	49.5	393	53.6
274	37.4	304	41.5	334	45.5	364	49.6	394	53.7
275	37.5	305	41.6	335	45.7	365	49.8	395	53.9
276	37.6	306	41.7	336	45.8	366	49.9	396	54.0
277	37.8	307	41.9	337	45.9	367	50.0	397	54.1
278	37.9	308	42.0	338	46.1	368	50.2	398	54.3
279	38.0	309	42.1	339	46.2	369	50.3	399	54.4
280	38.2	310	42.3	340	46.4	370	50.4	400	54.5
281	38.3	311	42.4	341	46.5	371	50.6	401	54.7
282	38.5	312	42.5	342	46.6	372	50.7	402	54.8
283	38.6	313	42.7	343	46.8	373	50.8	403	54.9
284	38.7	314	42.8	344	46.9	374	51.0	404	55.1
285	38.9	315	42.9	345	47.0	375	51.1	405	55.2
286	39.0	316	43.1	346	47.2	376	51.3	406	55.4
287	39.1	317	43.2	347	47.3	377	51.4	407	55.5
288	39.3	318	43.4	348	47.4	378	51.5	408	55.6
289	39.4	319	43.5	349	47.6	379	51.7	409	55.8
290	39.5	320	43.6	350	47.7	380	51.8	410	55.9
291	39.7	321	43.8	351	47.9	381	52.0	411	56.0
292	39.8	322	43.9	352	48.0	382	52.1	412	56.2

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

30° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
262	35.9	292	40.1	322	44.2	352	48.3	382	52.4
263	36.1	293	40.2	323	44.3	353	48.4	383	52.5
264	36.2	294	40.3	324	44.4	354	48.6	384	52.7
265	36.4	295	40.5	325	44.6	355	48.7	385	52.8
266	36.5	296	40.6	326	44.7	356	48.8	386	52.9
267	36.6	297	40.8	327	44.9	357	49.0	387	53.1
268	36.8	298	40.9	328	45.0	358	49.1	388	53.2
269	36.9	299	41.0	329	45.1	359	49.3	389	53.4
270	37.0	300	41.2	330	45.3	360	49.4	390	53.5
271	37.2	301	41.3	331	45.4	361	49.5	391	53.6
272	37.3	302	41.4	332	45.5	362	49.7	392	53.8
273	37.5	303	41.6	333	45.7	363	49.8	393	53.9
274	37.6	304	41.7	334	45.8	364	49.9	394	54.1
275	37.7	305	41.8	335	46.0	365	50.1	395	54.2
276	37.9	306	42.0	336	46.1	366	50.2	396	54.3
277	38.0	307	42.1	337	46.2	367	50.3	397	54.5
278	38.1	308	42.3	338	46.4	368	50.5	398	54.6
279	38.3	309	42.4	339	46.5	369	50.6	399	54.7
280	38.4	310	42.5	340	46.6	370	50.8	400	54.9
281	38.6	311	42.7	341	46.8	371	50.9	401	55.0
282	38.7	312	42.8	342	46.9	372	51.0	402	55.1
283	38.8	313	42.9	343	47.1	373	51.2	403	55.3
284	39.0	314	43.1	344	47.2	374	51.3	404	55.4
285	39.1	315	43.2	345	47.3	375	51.4	405	55.6
286	39.2	316	43.3	346	47.5	376	51.6	406	55.7
287	39.4	317	43.5	347	47.6	377	51.7	407	55.8
288	39.5	318	43.6	348	47.7	378	51.9	408	56.0
289	39.7	319	43.8	349	47.9	379	52.0	409	56.1
290	39.8	320	43.9	350	48.0	380	52.1	410	56.2
291	39.9	321	44.0	351	48.2	381	52.3	411	56.4

31° GRAVITY.

260	35.9	290	40.0	320	44.2	350	48.3	380	52.5
261	36.0	291	40.2	321	44.3	351	48.5	381	52.6
262	36.2	292	40.3	322	44.5	352	48.6	382	52.7
263	36.3	293	40.4	323	44.6	353	48.7	383	52.9
264	36.5	294	40.6	324	44.7	354	48.9	384	53.0
265	36.6	295	40.7	325	44.9	355	49.0	385	53.2
266	36.7	296	40.9	326	45.0	356	49.2	386	53.3
267	36.9	297	41.0	327	45.2	357	49.3	387	53.4
268	37.0	298	41.1	328	45.3	358	49.4	388	53.6
269	37.1	299	41.3	329	45.4	359	49.6	389	53.7
270	37.3	300	41.4	330	45.6	360	49.7	390	53.8
271	37.4	301	41.6	331	45.7	361	49.8	391	54.0
272	37.6	302	41.7	332	45.8	362	50.0	392	54.1
273	37.7	303	41.8	333	46.0	363	50.1	393	54.3
274	37.8	304	42.0	334	46.1	364	50.3	394	54.4
275	38.0	305	42.1	335	46.3	365	50.4	395	54.5
276	38.1	306	42.3	336	46.4	366	50.5	396	54.7
277	38.2	307	42.4	337	46.5	367	50.7	397	54.8
278	38.4	308	42.5	338	46.7	368	50.8	398	54.9
279	38.5	309	42.7	339	46.8	369	50.9	399	55.1
280	38.7	310	42.8	340	46.9	370	51.1	400	55.2
281	38.8	311	42.9	341	47.1	371	51.2	401	55.4
282	38.9	312	43.1	342	47.2	372	51.4	402	55.5
283	39.1	313	43.2	343	47.4	373	51.5	403	55.6
284	39.2	314	43.4	344	47.5	374	51.6	404	55.8
285	39.3	315	43.5	345	47.6	375	51.8	405	55.9
286	39.5	316	43.6	346	47.8	376	51.9	406	56.1
287	39.6	317	43.8	347	47.9	377	52.1	407	56.2
288	39.8	318	43.9	348	48.0	378	52.2	408	56.3
289	39.9	319	44.0	349	48.2	379	52.3	409	56.5

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

32° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
258	35.8	288	40.0	318	44.2	348	48.3	378	52.5
259	36.0	289	40.1	319	44.3	349	48.5	379	52.6
260	36.1	290	40.3	320	44.5	350	48.6	380	52.8
261	36.3	291	40.4	321	44.6	351	48.8	381	52.9
262	36.4	292	40.6	322	44.7	352	48.9	382	53.1
263	36.5	293	40.7	323	44.9	353	49.0	383	53.2
264	36.7	394	40.8	324	45.0	354	49.2	384	53.3
265	36.8	295	41.0	325	45.1	355	49.3	385	53.5
266	36.9	296	41.1	326	45.3	356	49.4	386	53.6
267	37.1	297	41.3	327	45.4	357	49.6	387	53.8
268	37.2	298	41.4	328	45.6	358	49.7	388	53.9
269	37.4	299	41.5	329	45.7	259	49.9	389	54.0
270	37.5	300	41.7	330	45.8	360	50.0	390	54.2
271	37.6	301	41.8	331	46.0	361	50.1	391	54.3
272	37.8	302	42.0	332	46.1	362	50.3	392	54.5
273	37.9	303	42.1	333	46.3	363	50.4	393	54.6
274	38.1	304	42.2	334	46.4	364	50.6	394	54.7
275	38.2	305	42.4	335	46.5	365	50.7	395	54.9
276	38.3	306	42.5	336	46.7	366	50.8	396	55.0
277	38.5	307	42.6	337	46.8	367	51.0	397	55.1
278	38.6	308	42.8	338	47.0	368	51.1	398	55.3
279	38.8	309	42.9	339	47.1	369	51.3	399	55.4
280	38.9	310	43.1	340	47.2	370	51.4	400	55.6
281	39.0	311	43.2	341	47.4	371	51.5	401	55.7
282	39.2	312	43.3	342	47.5	372	51.7	402	55.8
283	39.3	313	43.5	343	47.7	372	51.8	403	56.0
284	39.5	314	43.6	344	47.8	374	52.0	404	56.1
285	39.6	315	43.8	345	47.9	375	52.1	405	56.3
286	39.7	316	43.9	346	48.1	376	52.2	406	56.4
287	39.9	317	44.0	347	48.2	377	52.4	407	56.5

33° GRAVITY.

257	35.9	287	40.1	317	44.3	347	48.5	377	52.7
258	36.1	288	40.3	318	44.5	348	48.6	378	52.8
259	36.2	289	40.4	319	44.6	349	48.8	379	53.0
260	36.3	290	40.5	320	44.7	350	48.9	380	53.1
261	36.5	291	40.7	321	44.9	351	49.1	381	53.3
262	36.6	292	40.8	322	45.0	352	49.2	382	53.4
263	36.8	293	41.0	323	45.2	353	49.3	383	53.5
264	36.9	294	41.1	324	45.3	354	49.5	384	53.7
265	37.0	295	41.2	325	45.4	355	49.6	385	53.8
266	37.2	296	41.4	326	45.6	356	49.8	386	54.0
267	37.3	297	41.5	327	45.7	357	49.9	387	54.1
268	37.5	298	41.7	328	45.9	358	50.0	388	54.2
269	37.6	299	41.8	329	46.0	359	50.2	389	54.4
270	37.7	300	41.9	330	46.1	360	50.3	390	54.5
271	37.9	301	42.1	331	46.3	361	50.5	391	54.7
272	38.0	302	42.2	332	46.4	362	50.6	392	54.8
273	38.2	303	42.4	333	46.5	363	50.7	393	54.9
274	38.3	304	42.5	334	46.7	364	50.9	394	55.1
275	38.4	305	42.6	335	46.8	365	51.0	395	55.2
276	38.6	306	42.8	336	47.0	366	51.2	396	55.4
277	38.7	307	42.9	337	47.1	367	51.3	397	55.5
278	38.9	308	43.1	338	47.2	368	51.4	398	55.6
279	39.0	309	43.2	339	47.4	369	51.6	399	55.8
280	39.1	310	43.3	340	47.5	370	51.7	400	55.9
281	39.3	311	43.5	341	47.7	371	51.9	401	56.1
282	39.4	312	43.6	342	47.8	372	52.0	402	56.2
283	39.6	313	43.8	343	47.9	373	52.1	403	56.3
284	39.7	314	43.9	344	48.1	374	52.3	404	56.5
285	39.8	315	44.0	345	48.2	375	52.4	405	56.6
286	40.0	316	44.2	346	48.4	376	52.6	406	56.8

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

34° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
255	35.9	285	40.1	315	44.3	345	48.5	375	52.7
256	36.0	286	40.2	316	44.4	346	48.7	376	52.9
257	36.1	287	40.4	317	44.6	347	48.8	377	53.0
258	36.3	289	40.5	318	44.7	348	49.0	378	53.2
259	36.4	289	40.6	319	44.9	349	49.1	379	53.3
260	36.6	290	40.8	320	45.0	350	49.2	380	53.4
261	36.7	291	40.9	321	45.1	351	49.4	381	53.6
262	36.8	292	41.1	322	45.3	352	49.5	382	53.7
263	37.0	293	41.2	323	45.4	353	49.6	383	53.9
264	37.1	294	41.3	324	45.6	354	49.8	384	54.0
265	37.3	295	41.5	325	45.7	355	49.9	385	54.1
266	37.4	296	41.6	326	45.8	356	50.1	386	54.3
267	37.5	297	41.8	327	46.0	357	50.2	387	54.4
268	37.7	298	41.9	328	46.1	358	50.4	388	54.6
269	37.8	299	42.1	329	46.3	359	50.5	389	54.7
270	38.0	300	42.2	330	46.4	360	50.6	390	54.9
271	38.1	301	42.3	331	46.6	361	50.8	391	55.0
272	38.2	302	42.5	332	46.7	362	50.9	392	55.1
273	38.4	303	42.6	333	46.8	363	51.1	393	55.3
274	38.5	304	42.8	334	47.0	364	51.2	394	55.4
275	38.7	305	42.9	335	47.1	365	51.3	395	55.6
276	38.8	306	43.0	336	47.3	366	51.5	396	55.7
277	38.9	307	43.2	337	47.4	367	51.6	397	55.8
278	39.1	308	43.3	338	47.5	368	51.8	398	56.0
279	39.2	309	43.5	339	47.7	369	51.9	399	56.1
280	39.4	310	43.6	340	47.8	370	52.0	400	56.3
281	39.5	311	43.7	341	48.0	371	52.2	401	56.4
282	39.7	312	43.9	342	48.1	372	52.3	402	56.5
283	39.8	313	44.0	343	48.2	373	52.5	403	56.7
284	39.9	314	44.2	344	48.4	374	52.6	404	56.8

35° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
254	35.9	284	40.2	314	44.4	344	48.7	374	52.9
255	36.1	285	40.3	315	44.6	345	48.8	375	53.1
256	36.2	286	40.5	316	44.7	346	49.0	376	53.2
257	36.4	287	40.6	317	44.9	347	49.1	377	53.4
258	36.5	288	40.8	318	45.0	348	49.2	378	53.5
259	36.6	289	40.9	319	45.1	349	49.4	379	53.6
260	36.8	290	41.0	320	45.3	350	49.5	380	53.8
261	36.9	291	41.2	321	45.4	351	49.7	381	53.9
262	37.1	292	41.3	322	45.6	352	49.8	382	54.1
263	37.2	293	41.5	323	45.7	353	50.0	383	54.2
264	37.4	294	41.6	324	45.9	354	50.1	384	54.4
265	37.5	295	41.7	325	46.0	355	50.2	385	54.5
266	37.6	296	41.9	326	46.1	356	50.4	386	54.6
267	37.8	297	42.0	327	46.3	357	50.5	387	54.8
268	37.9	298	42.2	328	46.4	358	50.7	388	54.9
269	38.1	299	42.3	329	46.6	359	50.8	389	55.1
270	38.2	300	42.5	330	46.7	360	50.9	390	55.2
271	38.4	301	42.6	331	46.8	361	51.1	391	55.3
272	38.5	302	42.7	332	47.0	362	51.2	392	55.5
273	38.0	303	42.9	333	47.1	363	51.4	393	55.6
274	38.8	304	43.0	334	47.3	364	51.5	394	55.8
275	38.9	305	43.2	335	47.4	365	51.7	395	55.9
276	39.1	306	43.3	336	47.6	366	51.8	396	56.0
277	39.2	307	43.4	337	47.7	367	51.9	397	56.2
278	39.3	308	43.6	338	47.8	368	52.1	398	56.3
279	39.5	309	43.7	339	48.0	369	52.2	399	56.5
280	39.6	310	43.9	340	48.1	370	52.4	400	56.6
281	39.8	311	44.0	341	48.3	371	52.5	401	56.7
282	39.9	312	44.1	342	48.4	372	52.6	402	56.9
283	40.1	313	44.3	343	48.5	373	52.8	403	57.0

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

40° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons,	Pounds.	Gallons.
246	35.9	276	40.2	306	44.6	336	49.0	366	53.4
247	36.0	277	40.4	307	44.8	337	49.1	367	53.5
248	36.2	278	40.5	308	44.9	338	49.3	368	53.7
249	36.3	279	40.7	309	45.0	339	49.4	369	53.8
250	36.5	280	40.8	310	45.2	340	49.6	370	53.9
251	36.6	281	41.0	311	45.3	341	49.7	371	54.1
252	36.7	282	41.1	312	45.5	342	49.9	372	54.2
253	36.9	283	41.3	313	45.6	343	50.0	373	54.4
254	37.0	284	41.4	314	45.8	344	50.1	374	54.5
255	37.2	285	41.6	315	45.9	345	50.3	375	54.7
256	37.3	286	41.7	316	46.1	346	50.4	376	54.8
257	37.5	287	41.8	317	46.2	347	50.6	377	55.0
258	37.6	288	42.0	318	46.4	348	50.7	378	55.1
259	37.8	289	42.1	319	46.5	349	50.9	379	55.2
260	37.9	290	42.3	320	46.7	350	51.0	380	55.4
261	38.1	291	42.4	321	46.8	351	51.2	381	55.5
262	38.2	292	42.6	322	46.9	352	51.3	382	55.7
263	38.4	293	42.7	323	47.1	353	51.5	383	55.8
264	38.5	294	42.9	324	47.2	354	51.6	384	56.0
265	38.6	295	43.0	325	47.4	355	51.8	385	56.1
266	38.8	296	43.2	326	47.5	356	51.9	386	56.3
267	38.9	297	43.3	327	47.7	357	52.0	387	56.4
268	39.1	298	43.5	328	47.8	358	52.2	388	56.6
269	39.2	299	43.6	329	48.0	359	52.3	389	56.7
270	39.4	300	43.7	330	48.1	360	52.5	390	56.9
271	39.5	301	43.9	331	48.3	361	52.6	391	57.0
272	39.7	302	44.0	332	48.4	362	52.8	392	57.1
273	39.8	303	44.2	333	48.5	363	52.9	393	57.3
274	39.9	304	44.3	334	48.7	364	53.1	394	57.4
275	40.1	305	44.5	335	48.8	365	53.2	395	57.6

43° GRAVITY.

242	35.9	272	40.4	302	44.8	332	49.3	362	53.7
243	36.1	273	40.5	303	45.0	333	49.4	363	53.9
244	36.2	274	40.6	304	45.1	334	49.5	364	54.0
245	36.3	275	40.8	305	45.2	335	49.7	365	54.1
246	36.5	276	40.9	306	45.4	336	49.8	366	54.3
247	36.6	277	41.1	307	45.5	337	50.0	367	54.4
248	36.8	278	41.2	308	45.7	338	50.1	368	54.6
249	36.9	279	41.4	309	45.8	339	50.3	369	54.7
250	37.1	280	41.5	310	46.0	340	50.4	370	54.9
251	37.2	281	41.7	311	46.1	341	50.6	371	55.0
252	37.4	282	41.8	312	46.3	342	50.7	372	55.2
253	37.5	283	42.0	313	46.4	343	50.9	373	55.3
254	37.7	284	42.1	314	46.6	344	51.0	374	55.5
255	37.8	285	42.3	315	46.7	345	51.2	375	55.6
256	38.0	286	42.4	316	46.9	346	51.3	376	55.8
257	38.1	287	42.6	317	47.0	347	51.5	377	55.9
258	38.3	288	42.7	318	47.2	348	51.6	378	56.1
259	38.4	289	42.9	319	47.3	349	51.8	379	56.2
260	38.6	290	43.0	320	47.5	350	51.9	380	56.4
261	38.7	291	43.2	321	47.6	351	52.1	381	56.5
262	38.9	292	43.3	322	47.8	352	52.2	382	56.7
263	39.0	293	43.5	323	47.9	353	52.4	383	56.8
264	39.2	294	43.6	324	48.1	354	52.5	384	57.0
265	39.3	295	43.8	325	48.2	355	52.7	385	57.1
266	39.5	296	43.9	326	48.4	356	52.8	386	57.3
267	39.6	297	44.1	327	48.5	357	53.0	387	57.4
268	39.8	298	44.2	328	48.7	358	53.1	388	57.6
269	39.9	299	44.4	329	48.8	359	53.3	389	57.7
270	40.1	300	44.5	330	49.0	360	53.4	390	57.9
271	40.2	301	44.7	331	49.1	361	53.6	391	58.0

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

44° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
240	35.8	270	40.2	300	44.7	330	49.2	360	53.7
241	35.9	271	40.4	301	44.9	331	49.3	361	53.8
242	36.1	272	40.5	302	45.0	332	49.5	362	54.0
243	36.2	273	40.7	303	45.2	333	49.6	363	54.1
244	36.4	274	40.8	304	45.3	334	49.8	364	54.3
245	36.5	275	41.0	305	45.5	335	49.9	365	54.4
246	36.7	276	41.1	306	45.6	336	50.1	366	54.6
247	36.8	277	41.3	307	45.8	337	50.2	367	54.7
248	37.0	278	41.4	308	45.9	338	50.4	368	54.9
249	37.1	279	41.6	309	46.1	339	50.5	369	55.0
250	37.3	280	41.7	310	46.2	340	50.7	370	55.2
251	37.4	281	41.9	311	46.4	341	50.8	371	55.3
252	37.6	282	42.0	312	46.5	342	51.0	372	55.5
253	37.7	283	42.2	313	46.7	343	51.1	373	55.6
254	37.9	284	42.3	314	46.8	344	51.3	374	55.8
255	38.0	285	42.5	315	47.0	345	51.4	375	55.9
256	38.2	286	42.6	316	47.1	346	51.6	376	56.0
257	38.3	287	42.7	317	47.3	347	51.7	377	56.2
258	38.5	288	42.9	318	47.4	348	51.9	378	56.3
259	38.6	289	43.1	319	47.6	349	52.0	379	56.5
260	38.8	290	43.2	320	47.7	350	52.2	380	56.6
261	38.9	291	43.4	321	47.9	351	52.3	381	56.8
262	39.1	292	43.5	322	48.0	352	52.5	382	56.9
263	39.2	293	43.7	323	48.2	353	52.6	383	57.1
264	39.4	294	43.8	324	48.3	354	52.8	384	57.2
265	39.5	295	44.0	325	48.5	355	52.9	385	57.4
266	39.6	296	44.1	326	48.6	356	53.1	386	57.5
267	39.8	297	44.3	327	48.7	357	53.2	387	57.7
268	39.9	298	44.4	328	48.9	358	53.4	388	57.8
269	40.1	299	44.6	329	49.0	359	53.5	389	58.0

45° GRAVITY.

240	36.0	270	40.5	300	45.0	330	49.5	360	54.0
241	36.2	271	40.7	301	45.2	331	49.7	361	54.2
242	36.3	272	40.8	302	45.3	332	49.8	362	54.3
243	36.5	273	41.0	303	45.5	333	50.0	363	54.5
244	36.6	274	41.1	304	45.6	334	50.1	364	54.6
245	36.8	275	41.3	305	45.8	335	50.3	365	54.8
246	36.9	276	41.4	306	45.9	336	50.4	366	54.9
247	37.1	277	41.6	307	46.1	337	50.6	367	55.1
248	37.2	278	41.7	308	46.2	338	50.7	368	55.2
249	37.4	279	41.9	309	46.4	339	50.9	369	55.4
250	37.5	280	42.0	310	46.5	340	51.0	370	55.5
251	37.7	281	42.2	311	46.7	341	51.2	371	55.7
252	37.8	282	42.3	312	46.8	342	51.3	372	55.8
253	38.0	283	42.5	313	47.0	343	51.5	373	56.0
254	38.1	284	42.6	314	47.1	344	51.6	374	56.1
255	38.3	285	42.8	315	47.3	345	51.8	375	56.3
256	38.4	286	42.9	316	47.4	346	51.9	376	56.4
257	38.6	287	43.1	317	47.6	347	52.1	377	56.6
258	38.7	288	43.2	318	47.7	348	52.2	378	56.7
259	38.9	289	43.4	319	47.9	349	52.4	379	56.9
260	39.0	290	43.5	320	48.0	350	52.5	380	57.0
261	39.2	291	43.7	321	48.2	351	52.7	381	57.2
262	39.3	292	43.8	322	48.3	352	52.8	382	57.3
263	39.5	293	44.0	323	48.5	353	53.0	383	57.5
264	39.6	294	44.1	324	48.6	354	53.1	384	57.6
265	39.8	295	44.3	325	48.8	355	53.3	385	57.8
266	39.9	296	44.4	326	48.9	356	53.4	386	57.9
267	40.1	297	44.6	327	49.1	357	53.6	387	58.1
268	40.2	298	44.7	328	49.2	358	53.7	388	58.2
269	40.4	299	44.9	329	49.4	359	53.9	389	58.4

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

46° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
238	35.9	268	40.4	298	45.0	328	49.5	358	54.0
239	36.1	269	40.6	299	45.1	329	49.7	359	54.2
240	36.2	270	40.7	300	45.3	330	49.8	360	54.3
241	36.4	271	40.9	301	45.4	331	50.0	361	54.5
242	36.5	272	41.0	302	45.6	332	50.1	362	54.6
243	36.7	273	41.2	303	45.7	333	50.3	363	54.8
244	36.8	274	41.3	304	45.9	334	50.4	364	54.9
245	37.0	275	41.5	305	46.0	335	50.6	365	55.1
246	37.1	276	41.7	306	46.2	336	50.7	366	55.2
247	37.3	277	41.8	307	46.3	337	50.9	367	55.4
248	37.4	278	42.0	308	46.5	338	51.0	368	55.5
249	37.6	279	42.1	309	46.6	339	51.2	369	55.7
250	37.7	280	42.3	310	46.8	340	51.3	370	55.8
251	37.9	281	42.4	311	46.9	341	51.5	371	56.0
252	38.0	282	42.6	312	47.1	342	51.6	372	56.1
253	38.2	283	42.7	313	47.2	343	51.8	373	56.3
254	38.3	284	42.9	314	47.4	344	51.9	374	56.4
255	38.5	285	43.0	315	47.5	345	52.1	375	56.6
256	38.6	286	43.2	316	47.7	346	52.2	376	56.7
257	38.8	287	43.3	317	47.8	347	52.4	377	56.9
258	38.9	288	43.5	318	48.0	348	52.5	378	57.0
259	39.1	289	43.6	319	48.1	349	52.7	379	57.2
260	39.2	290	43.8	320	48.3	350	52.8	380	57.3
261	39.4	291	43.9	321	48.4	351	53.0	381	57.5
262	39.5	292	44.1	322	48.6	352	53.1	382	57.6
263	39.7	293	44.2	323	48.7	353	53.3	383	57.8
264	39.8	294	44.4	324	48.9	354	53.4	384	57.9
265	40.0	295	44.5	325	49.1	355	53.6	385	58.1
266	40.1	296	44.7	326	49.2	356	53.7	386	58.3
267	40.3	297	44.8	327	49.4	357	53.9	387	58.4

47° GRAVITY.

236	35.8	266	40.4	296	44.9	326	49.5	356	54.0
237	36.0	267	40.5	297	45.1	327	49.6	357	54.1
238	36.1	268	40.7	298	45.2	328	49.8	358	54.3
239	36.3	269	40.8	299	45.4	329	49.9	359	54.5
240	36.4	270	41.0	300	45.5	330	50.1	360	54.6
241	36.6	271	41.1	301	45.7	331	50.2	361	54.8
242	36.7	272	41.3	302	45.8	332	50.4	362	54.9
243	36.9	273	41.4	303	46.0	333	50.5	363	55.1
244	37.0	274	41.6	304	46.1	334	50.7	364	55.2
245	37.2	275	41.7	305	46.3	335	50.8	365	55.4
246	37.3	276	41.9	306	46.4	336	51.0	366	55.6
247	37.5	277	42.0	307	46.6	337	51.1	367	55.7
248	37.6	278	42.2	308	46.7	338	51.3	368	55.8
249	37.8	279	42.4	309	46.9	339	51.5	369	56.0
250	38.0	280	42.5	310	47.1	340	51.6	370	56.2
251	38.1	281	42.7	311	47.2	341	51.8	371	56.3
252	38.3	282	42.8	312	47.4	342	51.9	372	56.5
253	38.4	283	43.0	313	47.5	343	52.1	373	56.6
254	38.6	284	43.1	314	47.7	344	52.2	374	56.8
255	38.7	285	43.3	315	47.8	345	52.4	375	56.9
256	38.9	286	43.4	316	48.0	346	52.5	376	57.1
257	39.0	287	43.6	317	48.1	347	52.7	377	57.2
258	39.2	288	43.7	318	48.3	348	52.8	378	57.4
259	39.3	289	43.9	319	48.4	349	53.0	379	57.5
260	39.5	290	44.0	320	48.6	350	53.1	380	57.7
261	39.6	291	44.2	321	48.7	351	53.3	381	57.8
262	39.8	292	44.3	322	48.9	352	53.4	382	58.0
263	39.9	293	44.5	323	49.0	353	53.5	383	58.1
264	40.1	294	44.6	324	49.2	354	53.7	384	58.3
265	40.2	295	44.8	325	49.3	355	53.9	385	58.4

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

50° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
234	36. 1	264	40. 8	294	45. 4	324	50. 0	354	54. 6
235	36. 3	265	40. 9	295	45. 5	325	50. 2	355	54. 8
236	36. 4	266	41. 1	296	45. 7	326	50. 3	356	55. 0
237	36. 6	267	41. 2	297	45. 8	327	50. 5	357	55. 1
238	36. 7	268	41. 4	298	46. 0	328	50. 6	358	55. 3
239	36. 9	269	41. 5	299	46. 2	329	50. 8	359	55. 4
240	37. 0	270	41. 7	300	46. 3	330	50. 9	360	55. 6
241	37. 2	271	41. 8	301	46. 5	331	51. 1	361	55. 7
242	37. 4	272	42. 0	302	46. 6	332	51. 2	362	55. 9
243	37. 5	273	42. 1	303	46. 8	333	51. 4	363	56. 0
244	37. 7	274	42. 3	304	46. 9	334	51. 6	364	56. 2
245	37. 8	275	42. 4	305	47. 1	335	51. 7	365	56. 3
246	38. 0	276	42. 6	306	47. 2	336	51. 9	366	56. 5
247	38. 1	277	42. 8	307	47. 4	337	52. 0	367	56. 6
248	38. 3	278	42. 9	308	47. 5	338	52. 2	368	56. 8
249	38. 4	279	43. 1	309	47. 7	339	52. 3	369	57. 0
250	38. 6	280	43. 2	310	47. 8	340	52. 5	370	57. 1
251	38. 7	281	43. 4	311	48. 0	341	52. 6	371	57. 3
252	38. 9	282	43. 5	312	48. 2	342	52. 8	372	57. 4
253	39. 1	283	43. 7	313	48. 3	343	52. 9	373	57. 6
254	39. 2	284	43. 8	314	48. 5	344	53. 1	374	57. 7
255	39. 4	285	44. 0	315	48. 6	345	53. 2	375	57. 9
256	39. 5	286	44. 2	316	48. 8	346	53. 4	376	58. 0
257	39. 7	287	44. 3	317	48. 9	347	53. 6	377	58. 2
258	39. 8	288	44. 5	318	49. 1	348	53. 7	378	58. 3
259	40. 0	289	44. 6	319	49. 2	349	53. 9	379	58. 5
260	40. 1	290	44. 8	320	49. 4	350	54. 0	380	58. 7
261	40. 3	291	44. 9	321	49. 5	351	54. 2	381	58 8
262	40. 4	292	45. 1	322	49. 7	352	54. 3	382	59. 0
263	40. 6	293	45. 2	323	49. 9	353	54. 5	383	59. 1

60° GRAVITY.

220	35. 8	250	40. 7	280	45. 6	310	50. 5	340	55. 4
221	36. 0	251	40. 9	281	45. 8	311	50. 7	341	55. 6
222	36. 1	252	41. 1	282	45. 9	312	50. 8	342	55. 7
223	36. 3	253	41. 2	283	46. 1	313	51. 0	343	55. 9
224	36. 5	254	41. 4	284	46. 3	314	51. 2	344	56. 0
225	36. 6	255	41. 6	285	46. 4	315	51. 3	345	56. 2
226	36. 8	256	41. 7	286	46. 6	316	51. 5	346	56. 4
227	37. 0	257	41. 9	287	46. 8	317	51. 6	347	56. 5
228	37. 1	258	42. 0	288	46. 9	318	51. 8	348	56. 7
229	37. 3	259	42. 2	289	47. 1	319	52. 0	349	56. 9
230	37. 5	260	42. 4	290	47. 2	320	52. 1	350	57. 0
231	37. 6	261	42. 5	291	47. 4	321	52. 3	351	57. 2
232	37. 8	262	42. 7	292	47. 6	322	52. 4	352	57. 3
233	38. 0	263	42. 8	293	47. 7	323	52. 6	353	57. 5
234	38. 1	264	43. 0	294	47. 9	324	52. 8	354	57. 7
235	38. 3	265	43. 2	295	48. 1	325	52. 9	355	57. 8
236	38. 5	266	43. 3	296	48. 2	326	53. 1	356	58. 0
237	38. 6	267	43. 5	297	48. 4	327	53. 3	357	58. 2
238	38. 8	268	43. 7	298	48. 5	328	53. 4	358	58. 3
239	38. 9	269	43. 8	299	48. 7	329	53. 6	359	58. 5
240	39. 1	270	44. 0	300	48. 9	330	53. 8	360	58. 6
241	39. 3	271	44. 1	301	49. 0	331	53. 9	361	58. 8
242	39. 4	272	44. 3	302	49. 2	332	54. 1	362	59. 0
243	39. 6	273	44. 5	303	49. 4	333	54. 3	363	59. 1
244	39. 8	274	44. 6	304	49. 5	334	54. 4	364	59. 3
245	39. 9	275	44. 8	305	49. 7	335	54. 6	365	59. 5
246	40. 1	276	45. 0	306	49. 9	336	54. 7	366	59. 6
247	40. 2	277	45. 1	307	50. 0	337	54. 9	367	59. 8
248	40. 4	278	45. 3	308	50. 2	338	55. 1	368	59. 9
249	40. 6	279	45 5	309	50. 3	339	55. 2	369	60. 1

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

63° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
217	35.9	247	40.9	277	45.8	307	50.8	337	55.8
218	36.1	248	41.0	278	46.0	308	51.0	338	55.9
219	36.2	249	41.2	279	46.2	309	51.1	339	56.1
220	36.4	250	41.4	280	46.3	310	51.3	340	56.3
221	36.6	251	41.5	281	46.5	311	51.5	341	56.4
222	36.7	252	41.7	282	46.7	312	51.6	342	56.6
223	36.9	253	41.9	283	46.8	313	51.8	343	56.8
224	37.1	254	42.0	284	47.0	314	52.0	344	56.9
225	37.2	255	42.2	285	47.2	315	52.1	345	57.1
226	37.4	256	42.4	286	47.3	316	52.3	346	57.3
227	37.6	257	42.5	287	47.5	317	52.5	347	57.4
228	37.7	258	42.7	288	47.7	318	52.6	348	37.6
229	37.9	259	42.9	289	47.8	319	52.8	349	57.8
230	38.1	260	43.0	290	48.0	320	53.0	350	57.9
231	38.2	261	43.2	291	48.2	321	53.1	351	58.1
232	38.4	262	43.4	292	48.3	322	53.3	352	58.3
233	38.6	263	43.5	293	48.5	323	53.5	353	58.4
234	38.7	264	43.7	294	48.7	324	53.6	354	58.6
235	88.9	265	43.9	295	48.8	325	53.8	355	58.8
236	39.1	266	44.0	296	49.0	326	54.0	356	58.9
237	39.2	267	44.2	297	49.2	327	54.1	357	59.1
238	39.4	268	44.4	298	49.3	328	54.3	358	59.2
239	39.6	269	44.5	299	49.5	329	54.5	359	59.4
240	39.7	270	44.7	300	49.7	330	54.6	360	59.6
241	39.9	271	44.9	301	49.8	331	54.8	361	59.8
242	40.1	272	45.0	302	50.0	332	54.9	362	59.9
243	40.2	273	45.2	303	50.2	333	55.1	363	60.1
244	40.4	274	45.3	304	50.3	334	55.3	364	60.2
245	40.6	275	45.5	305	50.5	335	55.4	365	60.4
246	40.7	276	45.7	306	50.7	336	55.6	366	60.6

65° GRAVITY.

214	35.8	244	40.8	274	45.8	304	50.8	334	55.9
215	36.0	245	41.0	275	46.0	305	51.0	335	56.0
216	36.1	246	41.1	276	46.1	306	51.2	336	56.2
217	36.3	247	41.3	277	46.3	307	51.3	337	56.4
218	36.5	248	41.5	278	46.5	308	51.5	338	56.5
219	36.6	249	41.6	279	46.6	309	51.7	339	56.7
220	36.8	250	41.8	280	46.8	310	51.8	340	56.9
221	37.0	251	42.0	281	47.0	311	52.0	341	57.0
222	37.1	252	42.1	282	47.2	312	52.2	342	57.2
223	37.3	253	42.3	283	47.3	313	52.3	343	57.4
224	37.5	254	42.5	284	47.5	314	52.5	344	57.5
225	37.6	255	42.6	285	47.7	315	52.7	345	57.7
226	37.8	256	42.8	286	47.8	316	52.8	346	57.9
227	38.0	257	43.0	287	48.0	317	53.0	347	58.0
228	38.1	258	43.1	288	48.2	318	53.2	348	58.2
229	38.3	259	43.3	289	48.3	319	53.3	349	58.4
230	38.5	260	43.5	290	48.5	320	53.5	350	58.5
231	38.6	261	43.6	291	48.7	321	53.7	351	58.7
232	38.8	262	43.8	292	48.8	322	53.8	352	58.9
233	39.0	263	44.0	293	49.0	323	54.0	353	59.0
234	39.1	264	44.1	294	49.2	324	54.2	354	59.2
235	39.3	265	44.3	295	49.3	325	54.3	355	59.4
236	39.5	266	44.5	296	49.5	326	54.5	356	59.5
237	39.6	267	44.6	297	49.7	327	54.7	357	59.7
238	39.8	268	44.8	298	49.8	328	54.8	358	59.9
239	40.0	269	45.0	299	50.0	329	55.0	359	60.0
240	40.1	270	45.1	300	50.2	330	55.2	360	60.2
241	40.3	271	45.3	301	50.3	331	55.4	361	60.4
242	40.5	272	45.5	302	50.5	332	55.5	362	60.5
243	40.6	273	45.6	303	50.7	333	55.7	363	60.7

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

70° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
210	36. 0	240	41. 2	270	46. 3	300	51. 4	330	56. 6
211	36. 2	241	41. 3	271	46. 5	301	51. 6	331	56. 8
212	36. 4	242	41. 5	272	46. 6	302	51. 8	332	56. 9
213	36. 5	243	41. 7	273	46. 8	303	52. 0	333	57. 1
214	36. 7	244	41. 9	274	47. 0	304	52. 1	334	57. 3
215	36. 9	245	42. 0	275	47. 2	305	52. 3	335	57. 4
216	37. 1	246	42. 2	276	47. 3	306	52. 5	336	57. 6
217	37. 2	247	42. 4	277	47. 5	307	52. 6	337	57. 8
218	37. 4	248	42. 5	278	47. 7	308	52. 8	338	58. 0
219	37. 6	249	42. 7	279	47. 8	309	53. 0	339	58. 1
220	37. 7	250	42. 9	280	48. 0	310	53. 2	340	58. 3
221	37. 9	251	43. 0	281	48. 2	311	53. 3	341	58. 5
222	38. 1	252	43. 2	282	48. 4	312	53. 5	342	58. 6
223	38. 2	253	43. 4	283	48. 5	313	53. 7	343	58. 8
224	38. 4	254	43. 6	284	48. 7	314	53. 9	344	59. 0
225	38. 6	255	43. 7	285	48. 9	315	54. 0	345	59. 2
226	38. 8	256	43. 9	286	49. 1	316	54. 2	346	59. 3
227	38. 9	257	44. 1	287	49. 2	317	54. 4	347	59. 5
228	39. 1	258	44. 2	288	49. 4	318	54. 5	348	59. 7
229	39. 3	259	44. 4	289	49. 6	319	54. 7	349	59. 8
230	39. 4	260	44. 6	290	49. 7	320	54. 9	350	60. 0
231	39. 6	261	44. 8	291	49. 9	321	55. 0	351	60. 2
232	39. 8	262	44. 9	292	50. 1	322	55. 2	352	60. 4
233	40. 0	263	45. 1	293	50. 2	323	55. 4	353	60. 5
234	40. 1	264	45. 3	294	50. 4	324	55. 6	354	60. 7
235	40. 3	265	45. 5	295	50. 6	325	55. 7	355	60. 9
236	40. 5	266	45. 6	296	50. 8	326	55. 9	356	61. 0
237	40. 6	267	45. 8	297	50. 9	327	56. 1	357	61. 2
238	40. 8	268	46. 0	298	51. 1	328	56. 2	358	61. 4
239	41. 0	269	46. 1	299	51. 3	329	56. 4	359	61. 6

85° GRAVITY.

195	36. 0	225	41. 5	255	47. 0	285	52. 5	315	58. 1
196	36. 1	226	41. 7	256	47. 2	286	52. 7	316	58. 3
197	36. 3	227	41. 9	257	47. 4	287	52. 9	317	58. 4
198	36. 5	228	42. 0	258	47. 6	288	53. 1	318	58. 6
199	36. 7	229	42. 2	259	47. 8	289	53. 3	319	58. 8
200	36. 9	230	42. 4	260	47. 9	290	53. 5	320	59. 0
201	37. 1	231	42. 6	261	48. 1	291	53. 6	321	59. 2
202	37. 2	232	42. 8	262	48. 3	292	53. 8	322	59. 4
203	37. 4	233	43. 0	263	48. 5	293	54. 0	323	59. 6
204	37. 6	234	43. 1	264	48. 7	294	54. 2	324	59. 7
205	37. 8	235	43. 3	265	48. 9	295	54. 4	325	59. 9
206	38. 0	236	43. 5	266	49. 0	296	54. 6	326	60. 1
207	38. 2	237	43. 7	267	49. 2	297	54. 8	327	60. 3
208	38. 4	238	43. 9	268	49. 4	298	54. 9	328	60. 5
209	38. 5	239	44. 1	269	49. 6	299	55. 1	329	60. 7
210	38. 7	240	44. 2	270	49. 8	300	55. 3	330	60. 8
211	38. 9	241	44. 4	271	50. 0	301	55. 5	331	61. 0
212	39. 1	242	44. 6	272	50. 1	302	55. 7	332	61. 2
213	39. 3	243	44. 8	273	50. 3	303	55. 9	333	61. 4
214	39. 5	244	45. 0	274	50. 5	304	56. 1	334	61. 6
215	39. 6	245	45. 2	275	50. 7	305	56. 2	335	61. 8
216	39 8	246	45. 4	276	50. 9	306	56. 4	336	62. 0
217	40. 0	247	45. 5	277	51. 1	307	56. 6	337	62. 1
218	40. 2	248	45. 7	278	51. 3	308	56. 8	338	62. 3
219	40. 4	249	45. 9	279	51. 4	309	57. 0	339	62. 5
220	40. 6	250	46. 1	280	51. 6	310	57. 2	340	62. 7
221	40. 7	251	46. 3	281	51. 8	311	57. 3	341	62. 9
222	40. 9	252	46. 5	282	52. 0	312	57. 5	342	63. 1
223	41. 1	253	46. 6	283	52. 2	313	57. 7	343	63. 2
224	41. 3	254	46. 8	284	52. 4	314	57. 9	344	63. 4

TABLE OF THE SPECIFIC GRAVITY CORRESPONDING TO EACH DEGREE OF BAUMÉ'S HYDROMETER; ALSO, THE NUMBER OF POUNDS CONTAINED IN ONE UNITED STATES GALLON AT 60° F.

Baumé.	Specific gravity.	In one gallon.	Baumé.	Specific gravity.	In one gallon.
Deg.	*Deg.*	*Pounds.*	*Deg.*	*Deg.*	*Pounds.*
10	1.0000	8.33	43	0.8092	6.74
11	0.9929	8.27	44	0.8045	6.70
12	0.9859	8.21	45	0.8000	6.66
13	0.9790	8.16	46	0.7954	6.63
14	0.9722	8.10	47	0.7909	6.59
15	0.9655	8.04	48	0.7865	6.55
16	0.9589	7.99	49	0.7821	6.52
17	0.9523	7.93	50	0.7777	6.48
18	0.9459	7.88	51	0.7734	6.44
19	0.9395	7.83	52	0.7692	6.41
20	0.9333	7.78	53	0.7650	6.37
21	0.9271	7.72	54	0.7608	6.34
22	0.9210	7.67	55	0.7567	6.30
23	0.9150	7.62	56	0.7526	6.27
24	0.9090	7.57	57	0.7486	6.24
25	0.9032	7.53	58	0.7446	6.20
26	0.8974	7.48	59	0.7407	6.17
27	0.8917	7.43	60	0.7368	6.14
28	0.8860	7.38	61	0.7329	6.11
29	0.8805	7.34	62	0.7290	6.07
30	0.8750	7.29	63	0.7253	6.04
31	0.8695	7.24	64	0.7216	6.01
32	0.8641	7.20	65	0.7179	5.98
33	0.8588	7.15	66	0.7142	5.95
34	0.8536	7.11	67	0.7106	5.92
35	0.8484	7.07	68	0.7070	5.89
36	0.8433	7.03	69	0.7035	5.86
37	0.8383	6.98	70	0.7000	5.83
38	0.8333	6.94	75	0.6829	5.69
39	0.8284	6.90	80	0.6666	5.55
40	0.8235	6.86	85	0.6511	5.42
41	0.8187	6.82	90	0.6363	5.30
42	0.8139	6.78	95	0.6222	5.18

MEMORANDA.

One United States gallon of pure water = 231 cubic inches, contains 58,318 grains (or 3779.031 grams) = 8.331 pounds avoirdupois.
One imperial gallon of pure water = 277.276 cubic inches, contains 70,000 grains (or 4536.029 grams) = 10 pounds avoirdupois.
One cubic foot of pure water at 60° F. contains 1,000 ounces = 62.5 pounds avoirdupois.
To reduce imperial gallons to United States gallons, divide by 1.2.
To reduce United States gallons to imperial gallons, multiply by 1.2.
To reduce United States gallons to cubic feet, divide by 7.5.
To reduce cubic feet to United States gallons, multiply by 7.5.
To find the number of pounds avoirdupois in one cubic foot of any substance, multiply its specific gravity by 62.5.
To find the degree Baumé corresponding to any specific gravity:

$$\frac{140}{\text{sp. gr.}} - 130 = \text{B.}^\circ$$

To find the specific gravity corresponding to any degree Baumé:

$$\frac{140}{130 + \text{B.}^\circ} = \text{sp. gr.}$$

CHAPTER X.—PRODUCTION OF PETROLEUM IN THE UNITED STATES DURING THE CENSUS YEAR.

SECTION I.—THE CONDITIONS OF THE PROBLEM.

The localities which furnished the petroleum which entered the commerce of the United States during the census year were the region in northwestern Pennsylvania north and east of Pittsburgh; Mecca, in Trumbull county, Grafton, in Lorain county, and Washington county, Ohio; Pleasants, Wood, and Ritchie counties, West Virginia; Greene county, in southwestern Pennsylvania, and Glasgow, in Barren county, Kentucky.

The actual production of petroleum in the United States cannot be accurately given for any period of time; but an approximate estimate has been made up from all available sources of information, which is believed to be as nearly correct as can be made. The reports of the pipe-lines are believed to be correct; but they do not necessarily represent the production of oil. The statistics of production are usually made up of the total amount of oil run into the pipe-lines, an estimated amount handled by private lines and tank-cars, and "dump oil", handled in barrels, to be modified by adding or subtracting the amount of oil added to or subtracted from the stock in private and well tanks during the year.

The receipts of the incorporated pipe-lines have been reported in accordance with the requirements of a law of the state of Pennsylvania, and are easily accessible. I have received estimates of the oil handled by private lines and "dump oil", verified in some instances from independent sources, and, on the whole, I believe from well-informed and reliable parties.

The estimation of the amount of oil held in tanks at wells is at all times a problem of great difficulty. This difficulty is due to the fact that the business of producing oil is conducted in such a manner that the owners of the wells themselves do not know how much oil is in their tanks; and further, that they do not, in the aggregate, care to have the production of their wells known. Again, if the owners were anxious to have a census of the oil in tanks taken, it would have to be done simultaneously, as the amount in the tanks is constantly changing; and such concerted action as would be necessary would be beset with practical difficulties if it were unanimously agreed upon. Mr. J. C. Welch is in constant communication with a number of those producers who conduct their business in the most systematic manner, and really know from actual measurement how much oil runs into their tanks from day to day. From this exact information, and much other scarcely less reliable in its character, he makes up his daily and monthly reports, which are much the most reliable of any furnished in reference to this subject. I shall therefore quote from his reports in reference to this matter. In his report for August, 1879, he writes:

> There is no accumulation of stocks at wells anywhere except in the Bradford district. In the Bradford district, as is well known, the stocks at wells are very large, generally and probably rightly estimated in the vicinity of 1,500,000 barrels. By my table, given above, of comparative stocks at wells of the same owners July 1 and August 1, I find on the Bradford stocks my returns show an increase of a little over 3 per cent. Taking this increase on, say, 1,400,000 barrels, and it would make about 45,000 barrels of July production as having gone into stocks at wells. This would be about 1,500 barrels per day, and, added to July Bradford pipe-runs, would make my estimate of the production of that district saved in July a daily average of 39,556 barrels. In districts other than Bradford I think the pipe-runs of July substantially represent the production. In the light of these facts, and bringing forward my estimate of June, I estimate the production out of the ground, with the exception of what was lost in the Bradford district in July (of which no intelligent estimate can be made), as follows:

	July.	June.
	Barrels.	*Barrels.*
Butler & Armstrong	6,569	7,000
Clarion	5,034	5,100
Bullion	1,086	1,100
O. C. & A. R	3,679	3,900
Bradford	39,556	41,600
	55,924	58,700

In his September report he says:

> My returns of the stocks at wells of the same owners in the Bradford district August 1 and September 1 show great uniformity.

In his October report he writes:

> The Bradford stocks at wells October 1, compared with September 1, show a decline of 7 per cent. Taking this percentage from the presumed stocks at wells in the Bradford district September 1, 1,500,000 barrels, and it makes a decrease in September of 105,000, or 3,500 barrels a day going into pipe-runs.

In November his returns from the owners of the wells showed a gain of over 5 per cent., giving 1,470,000 barrels as the stock November 1. Owing to the loss during that month, the reported stocks December 1 were 1,395,000 barrels, the same as on October 1. Referring to his reports from well owners for December, in that for January, 1880, he says:

> This shows a decline in the Bradford stocks I received of 17 per cent., and substantially no change in the stocks in Butler and Clarion. Assuming a stock at the Bradford wells, December 1, of 1,400,000 barrels, which in the general estimate is not far from being right, a decline of 17 per cent. would reduce them during December 238,000 barrels.

In his February report he says:

The decline in the Bradford district on the above stocks in January was 6 per cent., against a decline in December of the stocks I received of 17 per cent.

His returns show a gain in February of 7 per cent., in March of 13 per cent., and in April of 14½ per cent. In his May report he states:

I have returns of 121,993 barrels of oil at 882 wells, May 1, making an average per well of 138 barrels. Taking the Bradford wells, May 1, at 6,600, it would make a total stock at those wells, May 1, of 910,800. * * * Drilling wells finished in May have been very considerable in number, and will show a high average of production, as the new territory now being operated upon between Bordell City and the Gray and Van Vleck wells has proved exceptionally rich.

In his report for June, which brings up his statistics to June 1, 1880, and closes the census year, he says:

I have received returns of 988 Bradford wells, June 1, with stocks at them, exclusive of wells that had their well stocks burned in May. These 988 wells had stocks, June 1, of 167,694 barrels, an average of 171 barrels. Taking 7,000 wells as the number in the Bradford district, June 1, and with this average the total Bradford well stocks, June 1, were 1,197,000. The large amount of oil lost in the Bradford district makes estimates on the production there an uncertain thing. The amount lost now is estimated as high as 10,000 and 12,000 barrels daily.

Mr. Welch estimated the average number of barrels per well for April as 138, and for May as 171; an increase in average well stocks during May of nearly 24 per cent. per well, and in total well stocks of over 31 per cent. In his report for August, 1880, he says:

I have received returns from 1,443 Bradford wells, August 1, showing stock at them of 270,821 barrels. The average per well is 187.6. Of these 1,443 wells, 1,078 belong to companies that have 30 wells or more, with an average per well of 187¼ barrels; the other 365 wells, from companies owning less than 30 wells, show an average per well of 188½ barrels. This, I think, shows clearly that my average of 187.6 for the entire number of wells is not vitiated on account of the returns being mostly from the larger companies.

I think this statement is good evidence of the general accuracy of Mr. Welch's conclusions, as the 1,443 wells were about one-fifth of the whole number at that time in the Bradford district.

In an editorial article, August 1, 1879, the Oil City *Derrick* remarks:

There is a large extent of territory in the Bradford field, but it has now 4,700 producing well.

In an article the following day the same paper remarks:

The *Derrick* is generally able to back up its assertions with figures, and we have prepared a table of all wells completed in the Bradford region since drilling began in 1875, with their production each month. These figures have been carefully compiled from the monthly oil reports, and are as accurate as can possibly be obtained without visiting personally every well in the region. We believe the table below does not vary from the actual producing wells 100.

I have completed this table from the files of the *Derrick* to September 1, 1880, and have added a column showing the average initial daily production per well for the productive wells drilled each month.

TABLE SHOWING THE NUMBER OF PRODUCTIVE WELLS DRILLED EACH MONTH, AND THEIR AVERAGE INITIAL DAILY PRODUCTION FOR EACH MONTH, FROM JULY 1, 1875, TO SEPTEMBER 1, 1880, IN THE BRADFORD DISTRICT.

Month.	Productive wells drilled.	Initial daily production.	Average.
1875.	*Number.*	*Barrels.*	*Barrels.*
July	6	174	29.00
August	2	50	25.00
September	3	94	31.33
October	8	160	20.00
November	3	44	14.67
December	1	25	25.00
Total	23	547	23.78
1876.			
January	11	155	14.09
February	11	252	22.91
March	14	508	36.29
April	17	286	16.82
May	25	392	15.68
June	34	544	16.00
July	31	507	16.35
August	45	652	14.49
September	29	412	14.21
October	52	550	10.58
November	46	450	9.78
December	42	390	9.29
Total	357	5,098	14.28
1877.			
January	53	490	9.24
February	37	349	9.43
March	61	631	10.34
April	42	510	12.14
May	54	514	9.52
June	52	515	9.90
July	33	516	15.64
August	48	506	10.54
September	84	1,158	13.79
October	153	2,091	13.66
November	114	1,368	12.00
December	143	2,502	17.50
Total	874	11,150	12.76
1878.	*Number.*	*Barrels.*	*Barrels.*
January	105	1,537	14.64
February	96	1,508	15.71
March	110	1,758	15.98
April	220	3,597	16.35
May	346	5,650	16.30
June	205	3,264	15.92
July	151	2,437	16.14
August	142	2,632	18.54
September	122	1,938	15.89
October	186	2,572	13.83
November	211	2,724	12.91
December	127	2,575	20.28
Total	2,021	32,192	15.93
1879.			
January	110	2,017	18.33
February	107	2,525	23.60
March	202	4,705	23.29
April	233	5,805	24.91
May	355	8,559	24.11
June	308	7,902	25.66
July	269	7,291	27.10
August	206	5,939	28.83
September	160	4,639	28.99
October	167	4,837	28.96
November	148	4,065	27.47
December	188	5,657	30.09
Total	2,453	63,941	26.07
1880.			
January	216	5,999	27.77
February	256	7,542	29.46
March	335	8,185	24.43
April	418	10,531	25.19
May	409	11,554	28.25
June	302	8,959	29.67
July	311	7,839	25.21
August	325	8,587	26.42
Total eight months	2,572	69,196	26.90
Total census year	3,080	84,141	27.32

GENERAL SUMMARY.

Years.	Productive wells drilled.	Initial daily production.	Average per well.
	Number.	*Barrels.*	*Barrels.*
1875, six months	23	547	23.78
1876, twelve months	357	5,098	14.28
1877, twelve months	874	11,150	12.76
1878, twelve months	2,021	32,192	15.93
1879, twelve months	2,453	63,941	26.07
1880, eight months	2,572	69,196	26.90
Total	8,300	182,124	21.94
At beginning of the census year	4,282	72,598	16.95
At end of the census year	7,362	156,739	21.29

An examination of this table shows that the 357 wells drilled in 1876 started off with a production of an average of only 11.48 barrels per day. At that time the Butler-Clarion district was at the height of its prosperity, with an occasional well of great value, leaving but little inducement for labor in the northern field. The 874 wells drilled the following year averaged a little better, but only 12.76 barrels per day. The 2,021 new wells of 1878 started off at a daily average of 15.93 barrels. In 1879 only 432 more wells were drilled, but their average initial daily production was 26.07 barrels, an increase of 63 per cent. The 4,282 wells that had been drilled in the four years preceding the beginning of the census year started off with a production of 72,598 barrels; the 3,080 wells drilled during the census year started off with a production of 84,141 barrels. Allowing the production of all the wells drilled previous to the census year to have been, June 1, 1879, 50 per cent. of their original flow, which is perhaps allowable when we consider that more than half were not twelve months' old, the production must have been increased during the census year 232 per cent. It is true that during this and the previous year the production of other fields had been declining, but the increased production in the Bradford district was beyond all precedent, and was due, first, to an increased number of wells, and, second, to a greatly increased average initial daily production, that average having risen from 19.41 barrels during the twelve months preceding the census year to 27.32 barrels during that year, an increase of 41.78 per cent.

Commenting on the monthly report of "oil operations" for May, 1879, the Oil City *Derrick*, in its issue of May 31, 1879, the day before the beginning of the census year, says:

As regards production and consumption, the supply and demand, we cannot discover anything in common between this and preceding years. Not one element of the outlook at the present time has a true counterpart in any preceding period. In 1874, when the market declined to about 40 cents, the outlook was bright as compared with the present. The daily production at that time was between 25,000 and 30,000 barrels. It is now not less than 50,000 or 52,000 barrels. The stock held in the oil regions then did not exceed 3,000,000 barrels. It is now not less than 7,000,000 barrels, and constantly augmenting. The decline at that time was attributable to the increased production caused by the striking of the large fourth-sand wells on the Butler county cross-belt. The territory where those wells were found was limited to a small area, and the gushers declined rapidly. Now the territory known to be prolific is almost boundless. * * * Developments in the Cole Creek district are being pushed with a persistence that bodes no good for the future price of the product. The producers are paying extravagant prices for the privilege of drilling.

On this day oil opened and closed at 73¾ cents per barrel.

June 28 the *Derrick's* special report on the petroleum market says:

We are informed by parties who know what they are talking about that the stock at the wells in the Bradford district at the present time is not less than 1,000,000 barrels.

August 29 the report for that date says:

The condition of tankage in the northern region has not improved, notwithstanding the enormous shipments during this month being full and running over. The matter is further complicated by the necessity the lines are under of emptying two 25,000-barrel tanks, which have sprung a leak. The status of the wells may be judged of from the fact that the first fifteen days of this month 60,000 barrels of wooden tankage was erected in the Bradford region, all of which is presumably full.

September 1 petroleum opened at Oil City at 65⅝ cents. The editor of the *Derrick* congratulated the trade that the monthly report for August showed fewer wells finished and but little addition to the daily production, and indulged the hope of improved prices. The report of petroleum markets for that date says:

If the well reports should show a decline, men will anxiously jump in and buy, to find ultimately that there is a sufficiency of petroleum to spare for all. *There only needs an advance of a few cents to set the walking-beam wagging and producers by the cars again, scrambling after more territory.*

The sagacity of this remark is exemplified in a remarkable manner in the history of the few months following. In the issue of September 12 the *Derrick* again warns its patrons of the dire effects of overproduction, and implores them to stop drilling, giving figures to show that the production was continually on the increase and stocks accumulating. Again, on the 20th, this paper refers to the quarrel then going on between the owners of tanks and the pipe-lines, and says:

It is easy to trace back all these troubles to overproduction. The owners of large tanks soon fill the capacity, and then seek means to have it emptied that it can be again filled from their flowing wells. Even if they put up new tanks, it is but a short time before they

are filled. We hear reports of 25,000-barrel tanks being built in many of the districts; yet how slight is all this new capacity when 2,000,000 barrels and over are backed up at the wells. Still the production goes on increasing. Our specials every morning give a long list of new wells. Consider the millions of stock on hand; the markets abroad nearly glutted with refined; storage capacity in the East nearly or quite filled; every well of the thousands in the Bradford district flowing daily into tanks already full or overflowing; pumping-wells forced to shut down or pump on the ground; then look at the new rigs going up and new wells daily coming in; the market hanging dead and lifeless at a ruinous figure; and ask yourself what must be the result of all this? Every week the production is greater than the week before; there is no use denying these facts, nor shirking the results they will bring.

Again, on the 23d, the editor remarks:

The runs on Saturday (20th) and Sunday (21st) were the largest ever known in the history of the trade. They amounted to over 132,000 barrels.

In the face of this enormous production the price of oil advanced, and on the 30th of September closed at $79\frac{5}{8}$ cents. The next day, in consequence of the decrease of rigs and completed wells in the Bradford district, it advanced to $82\frac{1}{2}$ cents. The development of oil territory continued to decrease until December, and the price advanced, with occasional fluctuations, until on December 3 it touched $128\frac{1}{2}$. The result of this movement was a general advance along the entire line of production and a gradual reduction of prices, culminating in the spring of 1880 in such an outflow of oil as rendered all attempts to transport it futile. The pipe-lines were taxed beyond their capacity; storage tanks and well tanks were all full, and the oil flowed out upon the ground; but the drilling went on, and the average production kept pace with the unparalleled number of wells.

The following statement gives the number of wells finished, the average number of barrels per day, and the average price of oil during the census year, divided into quarters:

	Number of wells.	Average number of barrels per day.	Average price per barrel.
First quarter	783	26.99	$0 70
Second quarter	475	28.51	85
Third quarter	660	29.09	1 10
Fourth quarter	1,162	26.05	83

The advance in price beyond $1 in December stimulated production to an extent hitherto unparalleled, and produced, near the close of the year, a reaction in prices that touched $72\frac{1}{2}$ cents on the 5th of May. Thus the year opened and closed with oil at nearly the same price.

As indicated in the foregoing pages, an estimate of the amount of third-sand oil produced during the census year embraces the following items:

1. Pipe-line runs.
2. Fluctuations in well stocks.
3. Oil wasted.
4. Oil burned in tanks outside of pipe-lines.
5. Oil marketed outside the pipe-lines, otherwise known as "dump oil".

Section 2.—WELL STOCKS.

Mr. Welch's monthly reports of the percentage of gain or loss in well stocks in the Bradford district, and his estimates of the actual stocks per well on May 1 and June 1, 1880, being based upon a sufficient number of reliable returns of individual wells, and carefully made, I think may be taken as substantially correct. They afford the means of revising his estimates of the gross Bradford well stocks for the earlier months of the census year, which like most published estimates for that period, are excessive. Taking his estimate of the average Bradford stocks on May 1, 1880, 138 barrels per well, and the total number of productive wells which had then been drilled, 6,953, we derive 959,514 barrels as the total Bradford well stocks at that date. In the same manner, applying his average per well on June 1, 1880, 171 barrels, to the total number of productive wells that had been drilled at that date, 7,362, we reach 1,258,902 barrels as the Bradford well stocks at the close of the census year. It is true that some of these wells were doing little or nothing, but the 988 wells upon which the average of 171 barrels per well were based included all classes of wells, and I regard the average as substantially correct.

The monthly fluctuations from July 1, 1879, to May 1, 1880, were reported by Mr. Welch as follows: In July a gain of 3 per cent.; in August no change; in September a loss of 7 per cent.; in October a gain of $5\frac{3}{8}$ per cent.; in November a loss equal to the gain in October, so that stocks stood December 1 precisely as they stood October 1; in December a loss of 17 per cent.; in January a loss of 6 per cent.; in February a gain of 7 per cent.; in March a gain of 13 per cent.; in April a gain of $14\frac{1}{2}$ per cent.

This is a net increase for the ten months from July 1, 1879, to May 1, 1880, of $3\frac{465}{1000}$ per cent. But the stocks at the later date, as we have found, were 959,514; consequently the stocks July 1, 1879, were 927,379, instead of

1,400,000, which Mr. Welch gave as the general estimate of the actual well stocks at that date, and which he himself adopted. Accepting, therefore, Mr. Welch's rates of the monthly fluctuations, and his conclusions as to the stocks of May and June, 1880, as correct, and taking the increase for June, 1879, as 14⅕ per cent., which is my judgment of the change for that month, we derive the following tabular statement of the Bradford well stocks for each month of the census year:

Month.	Whole number of productive wells drilled prior to the 1st of each month.	Total stocks at wells on the 1st of each month.	Number of barrels per well.	Percentage of increase or decrease of well stocks during each month.		Month.	Whole number of productive wells drilled prior to the 1st of each month.	Total stocks at wells on the 1st of each month.	Number of barrels per well.	Percentage of increase or decrease of well stocks during each month.	
				Increase.	Decrease.					Increase.	Decrease.
1879.		Barrels.		Per cent.	Per cent.	1880.		Barrels.		Per cent.	Per cent.
June	4,282	812,067	189.65	14⅕	....	January	5,728	737,319	128.72	....	6
July	4,590	927,379	202.04	3	....	February	5,944	693,080	116.60	7	....
August	4,859	955,200	196.58	....	....	March	6,200	741,596	119.61	13	....
September	5,065	955,200	188.59	....	7	April	6,535	838,003	128.23	14½	....
October	5,225	888,336	170.02	5⅜	....	May	6,953	959,514	138.00	31⅕	....
November	5,392	936,084	173.61	....	5 1/10	June	7,362	1,258,902	171.00	....	....
December	5,540	888,336	160.35	....	17						

An inspection of this table will show that the well stocks at the close of the year were 446,835 barrels more than at the beginning.

SECTION 3.—OIL THAT WAS WASTED AND BURNED.

Of the oil that ran to waste no estimate approaching accuracy can be made. Mr. Welch says, in his report for August, 1879:

> It is well known a large amount of oil went to waste in July on account of inability to take care of it. Early in the month there may have been 5,000 or 6,000 barrels per day lost in this way, and considerable loss continued most of the time during the month.

In his report for September he says:

> I may say that there was scarcely any oil lost in the district in August, while in July there was a large amount, and this month there is some being lost, although probably no great amount.

In his report for June, 1880, he says:

> The large amount of oil being lost in the Bradford district makes estimates on the production there an uncertain thing. The amount lost now is being estimated as high as 10,000 and 12,000 barrels daily.

On comparing these statements with the table given above, it will be seen that the losses that were reported from the unavoidable waste of oil in July, August, and September, 1879, and in May, 1880, corresponded in the first three months with those periods when the average stocks at wells were nearly 200 barrels each, and in the last instance with a sudden increase of those stocks by 31 per cent., which raised that average in one month from 138 to 171 barrels per well.

Returns from four large corporations owning 296 wells distributed in the Bradford district give a total loss from oil wasted of 13,620 barrels, an average of 46 barrels per well. These losses occurred in July, August, and September, 1879, and in May, 1880. There were nearly 5,000 wells in August, 1879, and nearly 7,000 in May, 1880. Assuming that this loss of 46 barrels per well occurred upon 6,000 wells, a total loss occurred of 276,000 barrels. I have placed this loss at 275,000 barrels, and believe this a conservative estimate, for the reason that this average is based on returns made by gentlemen who took great care to make them correct, and also because this loss occurred on the property of corporations using ample capital, with every means at their disposal to take care of their oil, if it were possible. The estimate made is under rather than over the amount actually lost.

On the 6th, 9th, and 12th of May, 1880, three very destructive fires occurred in the Bradford district. The report of operations in the issue of the Oil City *Derrick* for June 1 of that year says:

> In addition to the numerous isolated rigs burned in various parts of the field previous to and since May 6, the conflagration on that day, which destroyed Rew City, also burned 54 rigs at that point, and fires in other points in the field on that day destroyed 101 rig along Foster Brook, 19 in Tram Hollow, 6 in Tuna valley, and 2 on the East branch, making a total loss on that day of 182 rigs, beside a large amount of tankage and a considerable amount of oil. But three days intervened between the fires of the 6th and the disastrous conflagration which destroyed the village of Rixford, together with 54 rigs, 3 iron tanks, and about 75,000 barrels of oil. After another interval of three days the last and greatest of the series of fires swept through Tram Hollow, totally destroying the hamlets of Otto City, Middaughville, and Oil Center, and burning 300 rigs, a 25,000-barrel tank, and a large number of smaller tanks, with nearly 100,000 barrels of oil.

This gives a total of 536 rigs destroyed in these three fires, which, together with the isolated rigs burned during the month, have led to an estimated total of 600 rigs lost by fire in May, 1880. A fair estimate of stocks at these wells would be 150 barrels per well, amounting in the aggregate to 90,000 barrels of oil burned. The

25,000-barrel tank belonged to the United Lines. Deducting this 115,000 barrels from the 175,000, there remains 60,000 barrels of oil in small tanks burned. An editorial in the *Derrick* for May 13 concerning these fires remarks:

The oil region has never suffered so severely from fire within so short a time as the last week. Beginning with the conflagration which swept away Rew City last Thursday, the flames have crept over Rixford, portions of Summit, Red Rock, Foster Brook, and Four Mile, and are now raging in the vicinity of Duke Center. The disasters caused by these fires are the natural result of peculiar circumstances. For several weeks only a limited quantity of rain has fallen, and the ground is dry and parched, while in the woods which stretch in an unbroken line from one end of the Bradford field to the other the leaves and dried branches are like tinder. Scattered through this forest stand the rigs of the oil-wells, the ground about them saturated with oil and the boilers throwing up sparks day and night. Railroads also traverse some sections of it, and every one who has seen the burned patches of grass or wood each summer by the side of the track know how prolific a source of fire the locomotive is. Add to all these favorable materials for incipient conflagrations a high wind blowing almost a gale, as it has most of the time this spring, and the producers may feel that they have been lucky in escaping so well heretofore. Beside, the operator is careless, and sets his rigs and tanks in the midst of the forest, without clearing up the brush or leaves, or making any effort to escape the consequences if a fire breaks out in his vicinity. The lower oil country escaped such widespread disaster because the land was cleared of its forest. In Butler and Clarion counties more oil was produced in cultivated fields than in woods, while in Bradford there is more wood than cleared land; hence the chances of fire are greatly increased.

In the lower country there was no accumulation of stocks at wells; none wasted nor burned. The pipe-line runs therefore represent the production of that region.

I therefore estimate the production of third-sand oil out of the ground during the census year as in section 4.

SECTION 4.—ESTIMATE OF THE PRODUCTION OF THIRD-SAND OIL DURING THE CENSUS YEAR.

	Barrels.
1. Pipe-line receipts	22,628,286
2. Gain in well stocks	a446,855
3. Oil run to waste	275,000
4. Oil burned outside of well stocks and pipe-lines	60,000
5. "Dump oil" and oil run in private lines	578,670
Total	23,988,791

This oil was produced in—

	Barrels.
Northwestern Pennsylvania	23,835,982
Greene county, Pennsylvania	3,118
West Virginia and Washington county, Ohio	138,325
Glasgow, Kentucky	5,376
Total	23,988,791

The second-sand oil is produced near Franklin, Pennsylvania, and embraces also the B, C, D, and E grades of West Virginia oils. Of this oil there was produced in—

	Barrels.
West Virginia	68,392.88
Near Franklin, Pennsylvania	105,600.00
Grafton, Ohio	2,773.00
Total	176,765.88

Four-fifths of the first-sand oil comes from the first oil-sand of the Venango group near Franklin, Pennsylvania. The oils of this class were produced in—

	Barrels.
Franklin, Pennsylvania	86,857.00
West Virginia	12,536.00
Grafton, Ohio	1,386.00
Mecca, Ohio	900.00
Erie, Pennsylvania	25.00
Total	101,704.00

The specific gravity of this class of oils is 29.5° B. and lower. A few barrels of oil of this grade were produced on the Cumberland river, in Kentucky, but the actual figures could not be obtained. Probably the amount did not exceed 50 barrels.

The production at Smith's Ferry and Slippery Rock creek, Beaver county, Pennsylvania, has been placed by competent persons at 86,803 barrels. The following is a summary of these amounts:

	Barrels.
First-sand oil	101,704
Second-sand oil	176,766
Third-sand oil	23,988,791
Beaver county, Pennsylvania	86,803
Total	24,354,064

a By an inadvertence Professor Peckham, in preparing an abstract of this report for the Compendium, placed the gains in the Bradford well stocks at 327,852 barrels, instead of 446,855 barrels. In consequence, all the numbers into which these stocks enter were understated by 118,983 barrels.

The following is a summary of the total production of the different localities:

	Barrels.
Northwestern Pennsylvania	24,034,429
West Virginia and Washington county, Ohio	219,254
Beaver county, Pennsylvania	86,803
Glasgow, Kentucky	5,376
Grafton, Lorain county, Ohio	4,159
Greene county, Pennsylvania	3,118
Mecca, Trumbull county, Ohio	900
Erie, Pennsylvania	25
Total	24,354,064

I have been unable to visit California recently, and have not received any returns from that locality. A few thousands of barrels were produced there during the census year. A spring in Crook county, Wyoming, yielded 26 barrels of heavy lubricating oil, and others at the petroleum locality at Beaver Creek yielded 428 barrels. This production, while locally valuable, selling in some instances for $1 50 per gallon, is of little importance when considered in relation to the production of the entire country.

Section 5.—THE ACCUMULATION OF STOCKS.

It is evident from the preceding pages that for some time antecedent to and during the census year the production of petroleum, and especially of third-sand oil, had been in excess of any demand for it, and consequently there had been a gradual accumulation of stocks in excess of the amount required in handling the oil. This process of accumulation did not take place proportionally in all the districts producing petroleum, but took place mainly in the Bradford district of northwestern Pennsylvania.

In the Grafton and Mecca districts, Ohio, and at the Glasgow, Kentucky, district the stock of oil in tanks at wells would not probably exceed 150 barrels. The amount remained about constant during the year, as it represents only the stock necessary to the handling of the oil. The constant demand for the entire production of the Smith's Ferry district, including Slippery Rock creek, prevents any accumulation of stocks, and in consequence the well stocks are always low. These stocks, together with that in the hands of the Smith's Ferry Transportation Company, have been estimated by competent persons at 3,200 barrels on June 1, 1879. On the 31st of May, 1880, the same stocks were estimated at 3,000 barrels. In West Virginia and Washington county, Ohio, the well and tank stocks, together with the stocks held by the West Virginia Transportation Company on June 1, 1879, were 79,606 barrels, and the corresponding stocks on the 31st of May, 1880, were estimated at 50,848 barrels. In Greene county, Pennsylvania, the stocks were practically nothing.

In the heavy oil district near Franklin, Pennsylvania, there was an accumulation of this quality of oil, the stock at the beginning of the census year, allowing an estimated well stock of 3,000 barrels, being 19,898 barrels, and at the end 27,106 barrels.

In northwestern Pennsylvania, exclusive of the Franklin district, the net stocks in the custody of the pipe-lines June 1, 1879, and May 31, 1880, are represented in the following table:

	June 1, 1879.	May 31, 1880.
United Pipe Lines	$5,864,850	$9,851,885
Tide-Water Pipe Company	378,312	1,009,063
Tidioute and Titusville	189,767	270,718
Pennsylvania Transportation Company	9,855	3,271
Church run	1,751	....
Octave	11,642	14,558
Cherry Tree	4,602	....
Tidioute and Warren	11,198	15,129
Fox Farm	29,954	19,631
Charley and Shaeffer run	23,211	26,024
Emlenton	13,215	15,022
Total	6,538,357	11,225,301

To this must be added, for stocks outside the pipe-lines in the old territory above and below Oil City, as estimated by Mr. J. C. Welch, the following:

	Barrels.
June 1, 1879	293,474
May 31, 1880	382,318
Stock in iron tankage unattached to pipe-lines not otherwise given	150,000
	532,318

Mr. Welch's returns give an average of well stocks in the region outside the Bradford district of 32 barrels per well, an amount that remained practically constant throughout the year. The number of wells in this so-called "lower country" to which this average would apply is much more difficult to estimate than that of the Bradford

district. During the year previous to the beginning of the census year the decline of production in the Butler and Clarion districts had been rapid, and producers had been turning their attention to the Bradford district. As the census year advanced, the decreased production of the lower country became more pronounced, and the transfer of property to the Bradford district became almost equal to an hegira. Train after train of cars, loaded with all kinds of material used about an oil-well, even to old derricks in a few instances, went up the Allegheny Valley and Oil Creek roads to Bradford. No careful record of the wells drilled in the lower country was ever kept, hence the number producing at the beginning of the census year can never be known, nor can the number be known that ceased to produce and were pulled out during that year. Different estimates place the number pulled out at equal to double or treble the number drilled, but such divergent estimates show the worthlessness of all of them. Mr. Stowell puts the number of wells in the different districts of Pennsylvania, outside of Franklin, Bradford, and Beaver, at 6,693, but upon what basis this estimate rests I do not know. The following table from Stowell's *Petroleum Reporter* will give some idea of the value of this estimate as compared with the well-known changes taking place in the localities named:

NUMBER OF WELLS IN THE PENNSYLVANIA OIL-FIELDS, BY DISTRICTS, ON THE DATES GIVEN.

Name of district.	1879.									1880.					
	Jan. 31.	May 31.	June 30.	July 31.	Aug. 31.	Sept. 30.	Oct. 31.	Nov. 30.	Dec. 31.	Jan. 31.	Feb. 28.	Mar. 31.	Apr. 30.	May 31.	Dec. 31.
Butler, Parker, Clarion	4,560	4,350	4,300	4,260	4,200	4,200	4,200	4,175	4,075	4,000	4,000	4,000	4,050	4,050	3,713
Scrubgrass	270	270	270	260	260	270	270	270	270	272	272	272	272	272	272
Reno	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Oil City	360	355	355	350	350	350	350	350	350	350	350	345	345	345	345
Rouseville	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Rynd Farm	200	200	200	260	200	200	200	200	200	200	200	200	200	200	200
Columbia	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Petroleum Centre	45	43	43	43	40	40	40	40	40	40	40	40	40	40	40
Shamburg	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
Titusville	750	700	680	680	660	650	650	650	650	635	635	635	635	635	625
Pithole	75	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Fagundus	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Tidioute	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115
Warren	100	100	100	100	100	100	100	100	100	100	100	105	105	105	130
Total	6,965	6,693	6,623	6,568	6,485	6,485	6,485	6,460	6,360	6,272	6,272	6,272	6,322	6,322	6,000
Losses	....	287	70	55	83	....	....	25	......	88	....	....	....	....	320
Gains	....	....	....	....	....	....	....	....	....	....	....	....	50	....	....
Wells completed	....	110	26	23	45	16	45	59	73	56	33	38	34	32	211
Total losses	....	397	96	78	128	16	45	84	73	144	33	38	....	32	531
Total gains	....	....	....	....	....	....	....	....	....	....	....	....	84	....	....
Franklin	357	352	350	350	350	350	350	350	350	350	350	350	350	350	350
Wells completed	....	27	4	5	15	8	5	3	4	2	2	2	2	2	13
Losses	....	32	4	5	15	8	5	3	4	2	2	2	2	2	13

These figures show a total loss in the districts producing third-sand oil, due to wells abandoned, of 851 wells during the whole census year. The number of producing wells at the beginning of the census year was 6,693. During the year 480 wells were completed, which, added to the number producing at the beginning of the year, equals 7,173 wells. The number reported producing at the end of the year was 6,322; difference, 851. These wells were in most cases plugged with pine plugs or filled with sand.

I use these figures, not because I believe them to be correct, but because they are the only approximation to the truth now available; they vary in their subdivisions from any others published, and are not fully consistent with themselves. The *Petroleum World* gives the names of the parties who completed wells in the lower country as follows:

	Wells.	Production.	Dry.
	Number.	*Barrels.*	*Number.*
In Clarion county	61	564	16
In Butler and Armstrong counties	51	335	19
In Venango, Forest, and Warren counties	44	244	10
In Jefferson county	1	0	1
Near Byrom Center	171	2,089	30
Near Emlenton	7	27	3
Total	335	3,259	79

In the Franklin district, January 31, 1879, there were reported by Mr. Stowell 357 wells, which were reduced to 352 on May 31, 1879, the day before the census year commenced, and to 350 by June 30, continuing at that number until December 31, 1880, a period of eighteen months, during which period he reports 63 wells as having been completed. In the *Reporter* for January, 1880, he quotes a local correspondent of the *Franklin Spectator* as stating that "during the past year there were 123 wells drilled and 16 wells cleaned out and retubed. * * * The number of wells pumping January 1, 1879, was about 400, and taking the number of dry wells, 22, and the number abandoned during the year from the number pumping January 1, 1879, and the number drilled and cleaned out, it will leave the pumping wells, January 1, 1880, 475. Taking these figures, the average number of wells pumping for the year 1879 would be about 450".

Mr. Stowell reports only 80 wells of the 122 completed during 1879, and a total of 350 producing December 31, 1879, against 475 as given by the correspondent whom he quotes. Furthermore, it is highly improbable that in the old and nearly exhausted territory in the neighborhood of Rouseville and Rynd farm there should be for twenty-three months, from January 31, 1879, to December 31, 1880, 400 producing wells, and at the same time 90 at Shamburg, 150 at Fagundus, and 115 in the neighborhood of Tidioute. However, while calling attention to these manifest discrepancies, I repeat that this table furnishes the nearest approximation to the facts that is available. I shall therefore apply Mr. Welch's average of 32 barrels to 6,300 wells, and estimate the well stocks of the lower country at 201,600 barrels.

Summarized, the stocks of crude oil in the producing regions June 1, 1879, may be stated as follows:

ACCUMULATED STOCKS, JUNE 1, 1879.

	Barrels.
Pipe-line stocks, third sand	6,538,357
Well stocks, Bradford district	812,067
Well stocks, lower country	201,600
Iron-tankage stocks, outside of pipe-lines	293,474
Franklin stocks, heavy oil	19,898
Smith's Ferry	3,200
West Virginia and southern Ohio	79,606
Grafton and Mecca, Ohio, and Glasgow, Kentucky	150
	7 948,352

ACCUMULATED STOCKS, MAY 31, 1880.

	Barrels.
Pipe-line stocks, third sand	11,225,291
Well stocks, Bradford district	1,258,902
Well stocks, lower country	201,600
Iron tankage stocks, outside of pipe-lines	532,318
Franklin stocks, heavy oil	27,106
Smith's Ferry	3,000
West Virginia and southern Ohio	50,848
Grafton and Mecca, Ohio, and Glasgow, Kentucky	150
	13,299,215

From these summaries it will be seen that the total accumulated stocks in the whole country at the end of the census year was 13,299,215 barrels, and that the accumulation of stocks during the census year was 5,350,863 barrels. The stocks decreased during that year in the West Virginia and southern Ohio district 28,758 barrels; Smith's Ferry district, 200 barrels. They increased during the year in the Bradford district and lower country 5,372,613 barrels; Franklin heavy oil district, 7,208 barrels.

SECTION 6.—STATISTICS OF CAPITAL AND LABOR EMPLOYED IN THE PRODUCTION OF PETROLEUM DURING THE CENSUS YEAR.

The amount of capital that has been or that is invested in the production of petroleum is a problem involved in the deepest obscurity. Capital has often been ventured in this business legitimately without return, the investment proving a total loss. From such total loss to a return of enormous value the gradation has been by infinite steps. The actual cost of the wells which have been drilled since Drake's first well (1859) could be estimated with tolerable certainty, as the price per foot for drilling has been a well-known though fluctuating factor in investment from year to year; but what any given oil-well has cost, and upon what sum a dividend of profit or loss should be declared, is often scarcely known to the owners themselves. There are large corporations that have invested money systematically for years with uniform success; but any general estimate for the whole oil region based on the operations of such concerns would be very erroneous, for the business of such corporations has been managed with prudence and sagacity upon territory that has already been proved, and usually without great speculative risks. Producing oil has not been uniformly successful in individual enterprises, although, when taken as a whole, it may have been in a general way. The capital invested in producing oil involves as a

constant and well-known factor the cost of drilling and equipping wells, and also, as a fluctuating factor, the cost of the land privilege for drilling. This varies from nothing (when the original owner of the land drills his own well or offsets its cost for an equal share with those who drill it) to a bonus of from $100 to $500 an acre, in addition to a royalty of from one-sixteenth to one-fourth of the product. In other cases the fee to the land is purchased outright for large sums before the wells are drilled. Such purchases, made where land is proved, have often been very profitable business enterprises, while on the other hand they have as often proved worthless. A certain tract of land in the Oil Creek region was purchased by A., B. & Co. for $13,000 and sold to C. for $113,500 within three months. Three months later A., B. & Co. could have bought back the land for less than $10,000, it having in the mean time been proved of little value for oil. Transactions involving the loss of large sums have been so often repeated that those familiar with the oil regions frequently declare that, vast as the wealth may be which the product of petroleum represents, the losses have been fully equal to the gains. The vast number of wells that have produced nothing, the still larger number whose production has never covered the cost of drilling, together with the millions that have been wasted through fraud and reckless speculative risks, involve the loss of a vast sum which can never be accurately estimated. The area of the Bradford field was pretty clearly outlined by the end of the census year, and there were those who were declaring with added emphasis that each month had witnessed the culmination of its production, but it has continued to pour out from 50,000 to 80,000 barrels of oil a day for the last two years. If the fee to the 68,000 acres of the Bradford field was to be sold to-morrow, the estimated value, as given by different producers, would vary by so many millions of dollars as to make such estimates worthless for statistical purposes. The fact is, the present value of the land franchise of the oil-producing region is an unknown quantity, and must be so until it ceases to have value; then its past value at any given time can be estimated. The men of conservative temperament and those of sanguine temperament differ as widely as the poles are sundered in their estimates of the value of oil property. I shall not, therefore, attempt any estimate of the value of the land franchise of the oil-producing country, but shall confine my estimates to the number of wells drilled, cost of rigs, including engines, cost of casing and tubing, total cost of wells and rigs drilled during the census year, and the number of men employed in drilling wells and in producing oil during the census year.

These estimates will be made for the upper or Bradford district, the lower country, the Franklin district, and the Beaver district, Pennsylvania; the Grafton district and the Mecca district, Ohio; the West Virginia district and Washington county, Ohio; and the Glasgow, Kentucky, district.

During the census year there were 3,080 wells completed in the Bradford district, but at the close of the year there were 58 more rigs building and wells drilling than at the beginning. In the last month in the year 536 rigs were burned, about one-half of which were rebuilt immediately, and the rebuilding of the remainder was, on an average, half completed at the close of the census year, making the rebuilding equal to 75 per cent. of the whole number burned, or 402 rigs. It is fair to assume that the 47 rigs building at the end of the year in excess of those building at the beginning were one-half completed, and that the 11 wells drilling at the end of the year in excess of those drilling at the beginning were, with rigs completed, one-half drilled. This estimate would thus place the rigs built during the census year:

Rigs for wells completed	3,080
Rigs rebuilt	402
50 per cent. of rigs building at the close in excess of those building at the beginning of the year	23
Rigs to wells drilling at the close of the year in excess of those drilling at the beginning	11
Total	3,516

Each of these rigs required in building forty days of labor, making, for all, an aggregate of 140,640 days, or, estimating 300 working days to the year, equal to the continued labor through the year of 468 men, of whom 75 per cent., or 351 men, were skilled workmen and 117 ordinary laborers. Rigs cost during the census year from $325 to $400 each, according to the cost of placing the material where it was to be used, or an average of $362.50. This would give a total investment in rigs during the year of $1,274,550, of which $316,440 represents the cost of labor, estimated at the rate of $2 50 per day for skilled workmen and $1 50 per day for ordinary laborers. Returns of the cost of rigs built in the Bradford district during the census year from three large corporations are as follows: No. 1 built 25 rigs for $10,000; average cost, $400 each. No. 2 built 50 rigs for $17,500; average cost, $350 each. No. 3 built 29 rigs for $12,500; average cost, $431 each. Average cost of 104 rigs, $384 62 each.

Each of the 3,516 rigs built during the census year required for its construction 17,000 feet of lumber, of which 9,000 feet were sawed and 8,000 feet were hewn. This amount represents an aggregate consumption of 59,772,000 feet of lumber, of which probably 30 per cent. was hard wood.

It is almost impossible to estimate, with any approximation to accuracy, the capital invested in engines and boilers. There are engines in the oil regions fifteen years old, and some of them are to be found in the Bradford district, moved up there from the lower country. I have conversed with a number of oil producers on this subject, and find their opinions quite divergent. An estimate based on these opinions and my own observations would lead me to think that at least 90 per cent. of the wells in the Bradford region are supplied with engines and 60 per cent. with boilers, and an average valuation for these engines would not exceed $100 and $200 each for the

boilers. I have been informed that at least one-half the wells drilled in the Bradford district during the census year were supplied with engines and boilers from wells abandoned in the lower country, for which I make no estimate. For the other half, it is fair to assume that a large proportion, if not all, of the engines and boilers were new or nearly new. While the above estimate of valuations of boilers may be fair as applied to the whole field, it is too low by one-half for the engines and boilers purchased for new wells. I place the value, in round numbers, of—

Engines (50 per cent. of 90 per cent.) of (3,080 + 11) at $200	$278,200
Boilers (50 per cent. of 60 per cent.) of (3,080 + 11) at $400	370,800
	649,000

This would give an average valuation of $210 per well for all the boilers and engines purchased for the 3,091 wells drilled during the census year. That this valuation is not too high is further proved by returns which I have received from two large corporations with ample capital, both largely interested in the lower country and in the Bradford district. No. 1 drilled 29 wells; the boilers and engines cost $13,000. No. 2 drilled 45 wells; the boilers and engines cost $15,360. The average cost for No. 1 is $448; that for No. 2, $341. I have no doubt that a large percentage of the wells were drilled with poorer machinery than would be used by either of these parties.

The rig, boiler, and engine belong to the owner of the well; but the contractor who drills the well owns the drillers' tools and provides fuel for the engine and coal for the blacksmith. It is estimated that 2 per cent. of the wells use gas, which, practically costing nothing, reduces the number supplied with fuel to 3,024. Experienced producers estimate the consumption of fuel at an average of 100 cords of wood per well, amounting in the aggregate to 302,400 cords, and costing for cutting, at 90 cents per cord, $272,160. It is estimated that 500 men are employed in cutting wood in the Bradford district. The wood usually stands upon the land upon which the well is located, and, except for the cost of cutting, is considered of little or no value.

Each well requires for drilling two drillers and two tool-dressers, who are men skilled in the work which they perform. The tool-dressers are not blacksmiths, but men who are expert in the art of dressing tools. Each well also requires two teams, with teamsters, for hauling wood and material. From returns received from 104 wells drilled in the Bradford district in the census year, 25 drillers drilled the wells and 18 dressers dressed the tools. These wells were drilled more economically, as regards the amount of labor, than the average, as they were drilled by corporations employing very skillful men at maximum wages, from which I judge that a fair estimate would give a year's labor of a skilled workman to every two wells drilled, or, in round numbers, for the 3,086 wells drilled in the census year, a year's labor of 1,500 men, at an average rate of $3 per day. Estimating 300 working days to the year, the amount earned by them would equal $1,350,000. As many more laborers are employed, at an average compensation of $45 per month, earning an amount equal to $810,000. The outfit for drilling a well is worth $900, and is damaged an average of 25 per cent. by use in drilling one well, representing an investment of $694,350 during the census year. These sums show the cost to the contractor. The average contract price for drilling deep (2,000 feet) wells was 55 cents per foot. At this rate the 3,086 wells would represent an investment by the well-owner of $3,394,600. Such estimates are hardly worth the name of statistics, but are, I believe, as close an approximation to accuracy as can now be made.

Each well requires from 30 to 100 feet of 8-inch drive-pipe, which is driven to the bed-rock, and on an average 300 feet of casing, 5⅝ inches in diameter, and 2,000 feet of 2-inch pipe, through which the oil flows.

At an average of 50 feet of drive-pipe for each well, there were required during the census year for the 3,086 wells drilled 154,300 feet of 8-inch drive-pipe, 925,800 feet of 5⅝-inch casing, and 6,172,000 feet of 2-inch pipe.

It is extremely difficult to estimate the actual cost of this pipe, as the different manufacturers made bids for large contracts, and a proportion, impossible to ascertain accurately, was old pipe. One large corporation paid an average of $310 50 each for casing 29 wells; another an average of $210 each for 45 wells. In one case it is to be presumed a larger amount of old casing was used than in the other, but just what this difference of one-third signifies with reference to the whole number of wells it is impossible to ascertain. Prudent men, with ample capital, would sell old casing and use new, while men of limited means would purchase and use the old; but to what extent this was done it is now impossible to determine with accuracy. It is probable, however, that $210 per well is nearer an average price for casing for the entire Bradford district than $310 50. Returns from the same firms give an average expenditure of $343 per well for tubing 74 wells. These were firms using ample capital, and the average is no doubt too high for the whole field, $300 per well being without doubt an ample average cost at which to estimate tubing. Assuming that all of the drive-pipe was new and cost $3 per foot, the total cost would be as follows:

Drive-pipe	$462,900
Casing	648,060
Tubing	925,800
Total	2,036,750

The cost of torpedoes is subject to caprice. There are those who do not use them at all; some use small ones, others use very large ones. One firm torpedoed 25 wells at an aggregate cost of $9,982, average cost, $400; a second firm 29 wells for $3,000, average cost, $103; another firm 45 wells for $9,360, at an average cost of $208.

These firms and corporations are all managed by judicious, conservative men, of large experience, while a large proportion of the wells are drilled by men who operate recklessly and rely upon torpedoes to produce large and quick results. I regard $300 per well as a low estimate for torpedoes, amounting in the aggregate to $925,800.

These estimates foot up as follows:

Cost of 3,516 rigs	$1,274,550
Engines and boilers for 3,091 wells	649,000
Drilling 3,086 wells	3,394,600
Piping 3,086 wells	2,036,760
Torpedoing 3,086 wells	925,800
Total	8,280,710

Returns from eight of the largest firms and corporations doing business in the oil regions, having more than 20,000 acres under development and operating over 600 wells during the census year, give an average of five acres to one well, and assign to the land a value of $300 per acre for oil purposes. Upon this basis they estimate a general average cost of the land at $1,500 per well, and of the well itself from $2,500 to $3,000. At $2,500 each, the cost of the 3,080 wells completed during the census year would be $7,700,000; at $3,000 each the same wells would cost $9,240,000. My estimate of $8,280,710 is therefore a fair average estimate, as based upon that of the owners, of about 10 per cent. of the wells that had been drilled in the Bradford district at the beginning of the census year.

The approximate value of labor employed in building rigs was $316,440; in cutting wood, $272,160; in drilling wells, $2,160,000; total, $2,748,600. To this sum must be added the value of labor employed in operating and repairing wells already drilled, a service which requires the labor of a large number of men.

Returns from the owners of 590 wells show that they employ 275 men in pumping and gauging, and 34 men as overseers; a total of 309 men. Apply this average to the 4,000 wells in the Bradford district at the beginning of the census year, and it gives, in round numbers, 2,000 men, earning $45 per month, or an aggregate of $1,080,000, which makes up a total labor account for the Bradford field of $3,828,600.

The number of wells drilled in the lower country during the census year was 335. Their average depth has been placed at 1,400 feet, and the rigs and tools are the same as those used in the Bradford district, at the same average cost; but their lessened depth reduces the cost of both drilling and tubing. Three hundred and thirty-five rigs, at the average price of $362 50, would cost $121,437 50, and would require for their construction 5,695,000 feet of lumber, 3,015,000 of which would be sawed soft lumber and 2,680,000 hewn lumber. These wells would require for drilling 33,500 cords of wood, the cutting of which would cost $30,150.

I estimate the cost of engines and boilers in this district as averaging $300 per well, which, for 335 wells, would give a valuation of $100,500. Estimating the average of 50 feet of drive-pipe per well at $3 per foot, casing at $210 and tubing at $200 per well for an average depth of 1,400 feet, the cost of casing and tubing the 335 wells drilled in the lower country would be as follows:

Drive-pipe, 8-inch, 16,750 feet	$50,250
Casing, 5⅝-inch, 100,500 feet	70,350
Tubing, 2-inch, 469,000 feet	67,000

The drilling of 1,400-foot wells was worth during the census year 60 cents per foot, and at that rate the drilling of the 335 wells in the lower country cost $281,400.

Summarized, these estimates foot up as follows:

335 rigs, at $362 50 each	$121,437
Engines and boilers for 335 wells, at an average cost per well of $300	100,500
335 wells, drilled 1,400 feet each, at 60 cents per foot	281,400
Drive-pipe	50,250
Casing	70,350
Tubing	67,000
Total	690,937

The general estimate given by producers of large experience that 1,400-foot wells cost about $2,000 each confirms these detailed estimates; and at this rate the 335 wells would cost $670,000.

The employment of labor in the lower country is divided between drilling wells and caring for those already drilled. Unlike the wells in the Bradford district, nearly all of which were flowing during the census year, those of the lower country were all pumping-wells. The labor required in building 335 rigs, estimating 30 days of skilled labor at $2 50 and 10 days of ordinary labor at $1 50 per day, amounts to the labor of 33 carpenters, $25,125; 11 laborers, $5,025.

In drilling the wells there were required 175 skilled workmen at $3 per day, and as many more laborers at $45 per month, which would amount in a year as follows: 175 skilled workmen, at $3 per day, 300 days, $157,500; 175 laborers, $45 per month, $94,500.

The investment in drillers' tools, on an average of five wells to a set, amounts to $60,300.

The employment of labor in the lower country in the care of wells is proportionally greater, for reasons already stated.

Three corporations, owning 112 wells, all in the lower country, employed 74 men to care for them, four-fifths of whom were engaged in pumping and gauging. As these wells belonged to corporations having a thoroughly organized business, it is to be presumed that a minimum number of men are employed. Using these numbers as the basis of an average, the 6,000 wells that were cared for in the lower country during the census year required the services of 3,960 men; but I think it is fair to assume that 4,500 men were employed, at an average rate of compensation of $50 per month, which would make the aggregate sum paid in wages $2,700,000. The approximate value of labor employed in the lower country is, therefore—

In rig-building	$30,150
In cutting wood	30,150
In drilling wells	252,000
In caring for wells	2,700,000
Total	3,012,300

In estimating the investment in drilling wells and the value of labor employed in the Franklin district entirely different conditions must be considered. The wells are not more than 100 feet deep, and cost, on an average, only about $400 each. As a portion of the productive territory is owned by farmers, who in some instances drill the wells themselves and pump them at intervals as other work may slacken, it will be readily perceived that a much larger number of persons are interested in the production of oil, and find partial occupation in it, than would be necessary to carry on the business if constantly employed. In the most productive portion of the field the wells are constantly pumped six days in the week on the sucker-rod plan, from 12 to 40 wells being by this method pumped by one engine. There were 475 productive wells January 1, 1880, and I shall assume that 450 was the average for the census year, of which 400 were pumped constantly. The rigs used here are only about 30 feet in height.

Drilling in this district was comparatively active during the census year, an average of about 10 wells per month having been completed, with an average daily production of about 2 barrels each. The drilling of these wells could not have employed constantly more than 50 men, including the rig-builders, and their care, allowing 5 men to 20 wells, would employ 120 men. Summarized, the items appear as follows:

Cost of 120 wells	$48,000
Labor of 50 men, at $50 per month	30,000
Labor of 120 men, at $50 per month	72,000

In the Beaver district it is estimated there were 200 wells, 15 wells being drilled during the year. These wells are about 600 feet deep, and cost about $700 each. The rigs used are low and comparatively inexpensive, and the pumping is done with sucker-rods. Probably 75 men, at $50 per month, is a maximum estimate for the labor employed in this district. Summarized the items appear as follows:

Cost of 15 wells, at $700 each	$10,500
Labor of 75 men for one year, at $50 per month	45,000

At Belden and at Grafton, Lorain county, Ohio, 72 paying and twice as many more unproductive wells have been drilled, generally from 60 to 250 feet in depth, the deepest yielding the lightest oil, of which about 20 were producing during the census year. Wells cost here from $30 to $40 each, exclusive of the rig and machinery, which are moved about as required. The oil industry here gives employment to about 10 men, and their labor, at $50 per month, for one year, amounts to $6,000.

In the Mecca district the cost of operating for oil is reduced to a minimum. The wells are from 40 to 70 feet deep. A rig costs only $20, and is moved about as required. A rig was hired, and three wells were put down at a total expense of $100.

Probably 20 wells, at an estimated cost of $40 each, were drilled during the census year. It is estimated that 15 men are fully employed here in producing oil. Very few wells are pumped by machinery, a wooden conductor being carried down to the rock; and after the well is drilled and the production has run down everything is removed but this conductor. The well is then pumped at intervals with a sand pump. There are several hundred wells that are pumped in this manner, but the exact number would be very difficult to ascertain. Summarized, the items appear as follows: Cost of 20 wells, at $40, $800; labor of 15 men, at $50 per month, one year, $9,000.

The West Virginia and Washington county (Ohio) oil district is the most peculiar in the country. It has produced oil for a long time, and yields a great variety. The number of wells in this region is about 600. Some of them, yielding heavy and valuable oil, have been pumped since 1865 and 1866; others, yielding lighter oils, have been abandoned, and others still that had been abandoned have been cleaned out and pumping has been resumed. A few wells are being drilled there every year. In the absence of records, it has been estimated that the number of pumping wells has remained about the same for several years, the new ones about equaling those abandoned. I could not ascertain that more than 120 wells were drilled in the district during the census year, the depths

varying from 150 to 1,500 feet, as the well penetrates the different horizons at which oil is found. Very few wells, however, have been put down to the 1,500-foot level, and perhaps an equally small number have proved remunerative at the 150- to 200-foot level. The average depth is about 750 feet, and the average cost is estimated at $1,000. Both skilled and ordinary labor is cheaper in this section than in northwestern Pennsylvania, skilled labor being reported here to be worth during the census year from $2 to $2 50 per day, against $2 50 to $3 50 in Pennsylvania, and ordinary labor from $1 to $1 50, against $1 75 to $2 in Pennsylvania. A large number of wells are pumped here by one engine, but instead of a sucker-rod connection the pump rod is attached to a wheel, over which passes an endless wire rope. The uneven surface of the country, as well as the greater depth of the wells, renders this method of transmitting power necessary; but while it is more expensive, it is more reliable.

From returns received I estimate the average cost of the 120 rigs built during the census year at $250 each, requiring twenty-four days of skilled and eight days of ordinary labor and 12,000 feet of lumber in their construction. Coal is used as fuel in this section, the wells often passing through the veins. I estimate very few, if any, new engines and boilers in use for drilling these wells. This section has produced oil since 1861, and some of the machinery used is very old. In drilling the machinery is attached to a gang of wells by an endless rope, and is run without any increase in the expense account. Wooden conductors are used. I estimate an average expense of $125 as ample to cover the cost of casing, and an average of 500 feet for each would include all of the tubing required. The cost per foot for drilling would not vary much from 60 cents per foot. Summarized, these estimates appear as follows:

120 rigs, at $250 each	$30, 000
120 wells drilled	54, 000
Casing, $125 each	15, 000
Tubing	9, 000
	108, 000

The labor employed for the year is estimated as follows:

In rig-building, 10 men, earning	$7, 200
In rig-building, 3 men, earning	960
In drilling wells, 25 men, earning	15, 000
In caring for wells, 250 men, earning	150, 000
	173, 160

On Boyd's creek, near Glasgow, Kentucky, there were five wells in operation during the census year, furnishing employment to seven men, including teamsters, at an average compensation of $35 per month, the wages amounting to $2,940.

The following table represents in a tabulated form the statistics of this section:

STATISTICS OF THE INVESTMENT OF CAPITAL AND THE EMPLOYMENT OF LABOR IN THE PRODUCTION OF PETROLEUM DURING THE YEAR ENDING MAY 31, 1880.

Name of district.	No. of wells drilled.	No. of dry holes.	No. of rigs built.	Cost of rigs.	Cost of engines and boilers.	Cost of drive-pipe.	Cost of casing.	Cost of tubing.	Cost of torpedoes.	Cost of drilling.	Total cost of wells.	Estimated number of skilled workmen.	Average rate of wages.
Bradford, Pennsylvania	3, 080	53	3, 516	$1, 274, 550	$649, 000	$462, 900	$648, 060	$925, 800	$925, 800	$3, 394, 600	$8, 280, 710	1, 851	$2 50—4 00
Lower country, Pennsylvania	335	79	335	121, 437	100, 500	50, 250	70, 350	67, 000	....	281, 400	690, 937	208	2 50—4 00
Franklin, Pennsylvania	120	15	120	....	....	....	....	....	....	....	48, 000	15	2 50—4 00
Beaver county, Pennsylvania	15	....	15	....	....	....	....	....	....	....	10, 500	12	2 50—4 00
Grafton, Ohio	....	....	....	....	....	....	....	....	....	....	....	....	....
Mecca, Ohio	20	....	....	....	....	....	....	....	....	....	800	....	....
West Virginia and southern Ohio	120	....	120	30, 000	....	....	15, 000	9, 000	....	54, 000	120, 000	25	2 00—2 50

Name of district.	Estimated number of ordinary laborers.	Average rate of wages.	Estimated number of wood-choppers.	Rate paid per cord.	Total number of men employed.	Total amount of wages paid.	Estimated number of men employed in drilling wells.	Estimated number of men employed in caring for wells.	Estimated amount of feet of lumber used in rigs.	Estimated amount of cords of fuel used in drilling wells.	Total production in barrels.
Bradford, Pennsylvania	3, 617	$1 50—2 00	500	$0 90	5, 968	$3, 828, 600	3, 000	2, 000	59, 772, 000	302, 400	} 23, 828, 589
Lower country, Pennsylvania	4, 686	1 50—2 00	50	....	4, 944	3, 012, 300	350	4, 500	5, 695, 000	33, 500	
Franklin, Pennsylvania	155	1 50—2 00	....	....	170	102, 000	50	120	600, 000	....	86, 857
Beaver county, Pennsylvania	63	1 50—2 00	....	....	75	45, 000	10	60	225, 000	....	86, 803
Grafton, Ohio	....	....	....	....	10	6, 000	....	10	....	....	4, 159
Mecca, Ohio	....	....	....	....	15	9, 000	....	15	....	....	900
West Virginia and southern Ohio	263	1 00—1 50	....	....	288	173, 160	25	250	1, 440, 000	....	219, 254
Glasgow, Kentucky	....	....	....	....	7	2, 940	....	....	....	....	5, 370
Greene county, Pennsylvania	....	....	....	....	....	....	....	....	....	....	3, 118
Erie, Pennsylvania	....	....	....	....	....	....	....	....	....	....	25

Cost of raising oil: Flowing wells in the Bradford district, 6 to 8 cents per barrel; pumping wells in the lower country, 60 to 80 cents; pumping wells in Franklin district, $3 per barrel.

To this may be added the following table, showing the estimated number of wells at the beginning and the end of the census year in the United States east of the Mississippi river:

Name of district.	Estimated number of producing wells June 1, 1879.	Estimated number of producing wells May 31, 1880.	Number completed during census year.	Dry holes.
Bradford, Pennsylvania	4,282	7,362	3,080	53
Lower country, Pennsylvania	6,693	6,322	335	79
Franklin, Pennsylvania	400	500	120	15
Beaver county, Pennsylvania	200	200	15	?
Grafton, Ohio	20	20	?	?
Mecca, Ohio	?	?	20	?
West Virginia and southern Ohio	500	600	120	?
Glasgow, Kentucky	5	5		
Total	12,100	15,009	3,690	147

Section 7.—GENERAL STATISTICS RELATING TO THE PRODUCTION OF THIRD-SAND PETROLEUM.

In illustration of this section I have been so fortunate as to secure the accompanying diagrams, prepared by Mr. Charles A. Ashburner, of Philadelphia, especially for this work, from the statistical tables of Stowell's *Petroleum Reporter*. No. I is a graphic representation of the total production by years of the different districts, by which the date of discovery, expansion, and contraction of the production of the different districts is noted; No. II shows the comparative volume of the total production of the different districts. No. III shows the comparative expansion and contraction of the total yearly production, with the total value in greenbacks and gold, from 1859 to 1880, inclusive. On pages 149, 150, and 151 are statistical tables from another source, which vary only slightly from the preceding in the aggregate, and present the matter in detail. On page 150 is a statistical statement, made by the United Pipe Lines, that offers its own explanation. On page 151 is a table giving some comparative miscellaneous pipe-line statistics that are included in the census year, taken from the *Titusville Herald* of April 11, 1881, except the averages for the census year. The following estimate of stocks in the oil region on the dates named is given for what it is worth, as the authority is unknown:

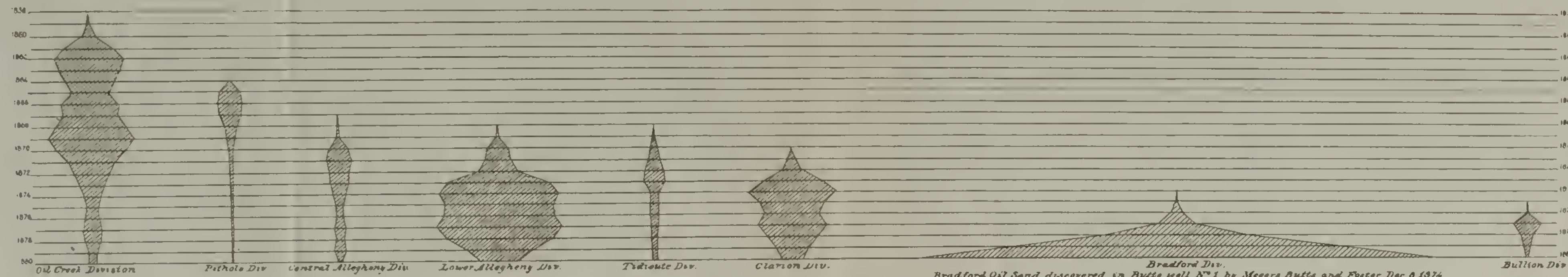
	Barrels.		Barrels.
February, 1868	534,000	February, 1874	1,248,919
February, 1869	264,000	February, 1875	4,250,000
February, 1870	340,751	February, 1876	3,585,143
February, 1871	537,000	February, 1877	2,604,128
February, 1872	623,048	February, 1878	3,555,342
February, 1873	1,085,435	February, 1879	5,385,523

STATEMENT SHOWING THE YEARLY PRODUCTION, AVERAGE YEARLY PRICE, AND VALUE, IN CURRENCY, OF ALL OIL PRODUCED FROM 1860 TO DECEMBER 31, 1880, BOTH INCLUSIVE.

Year.	Number of barrels.	Average price per barrel.	Amount.
Total	156,888,331		$334,871,063 84
1860	500,000	$9 60	4,800,000 00
1861	2,113,609	49	1,035,668 41
1862	3,056,690	1 05	3,209,524 50
1863	2,611,309	3 15	8,225,623 35
1864	2,116,109	9 87½	20,896,576 37
1865	2,497,700	6 59	16,459,843 00
1866	3,597,700	3 74	13,455,398 00
1867	3,347,300	2 41	8,066,993 00
1868	3,646,117	3 62½	13,217,174 12
1869	4,215,000	5 63	23,730,450 00
1870	5,260,745	3 89¾	20,503,753 63
1871	5,205,341	4 34	22,591,179 94
1872	5,890,248	3 64	21,440,502 72
1873	9,890,964	1 83	18,100,464 12
1874	10,809,852	1 17	12,647,526 84
1875	8,787,506	1 35	11,863,133 10
1876	8,968,906	2 56¼	22,982,821 62
1877	13,135,771	2 42	31,788,565 82
1878	15,163,462	1 19	18,044,519 78
1879	20,041,581	85⅞	17,210,707 68
1880	26,032,421	94½	24,600,637 84

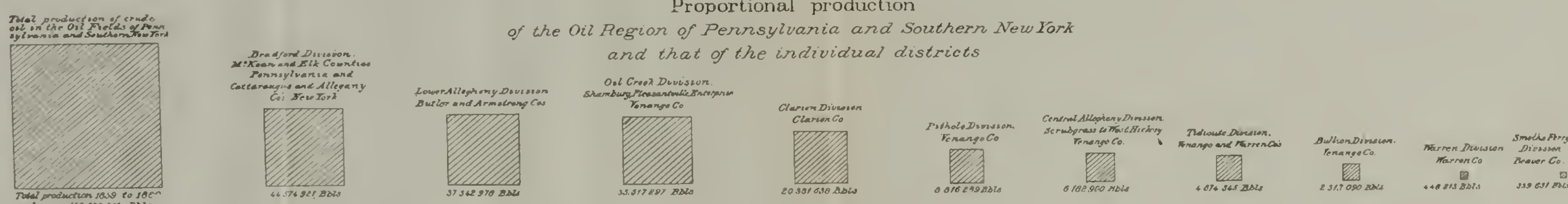
Average price per barrel for 21 years, $2 13+.

CHART
N° 1
Showing the annual production of **Petroleum**
and
Development of the individual districts in the
OIL REGION
of Pennsylvania and Southern New York



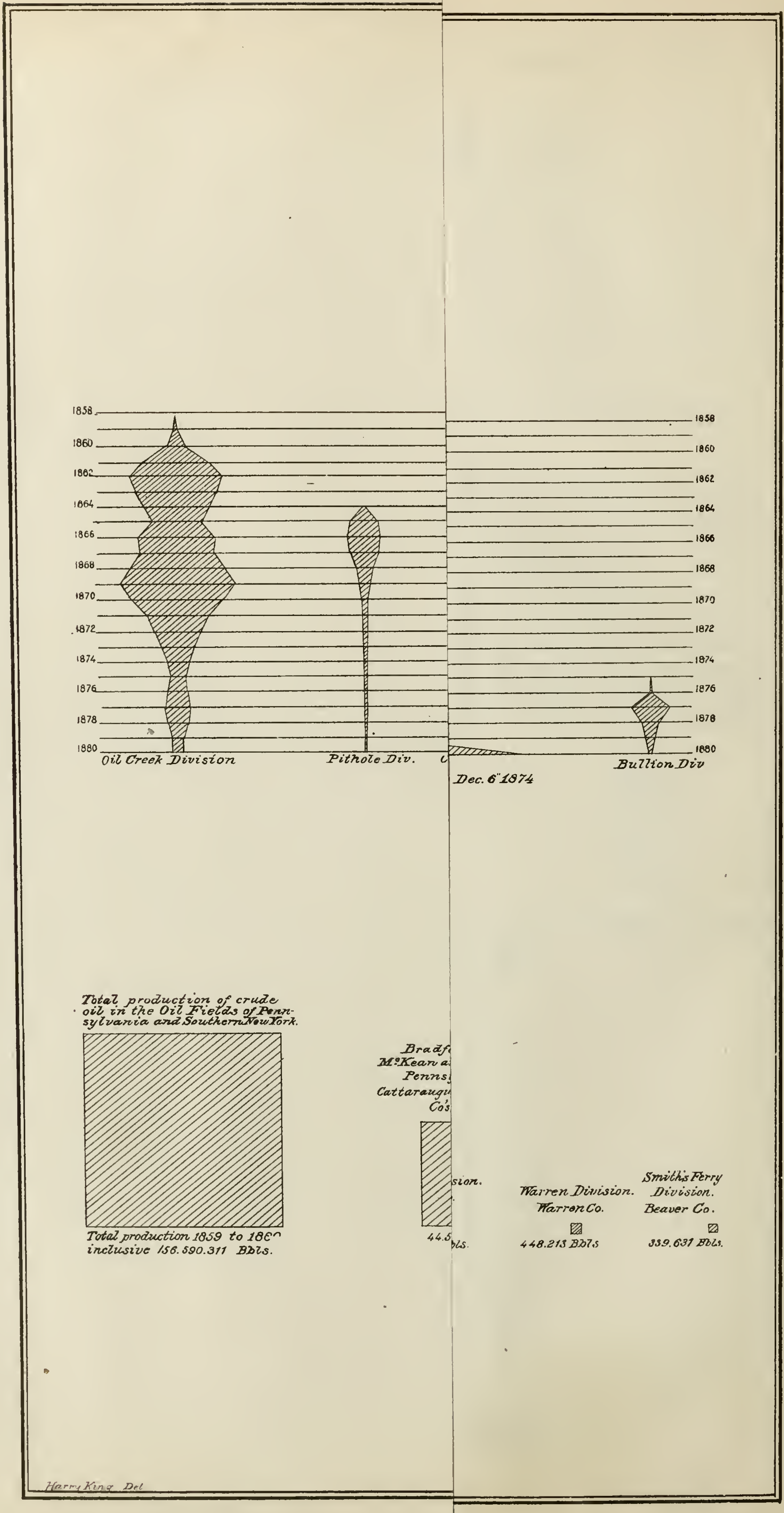
Scale.

CHART
N° 2
Proportional production
of the Oil Region of Pennsylvania and Southern New York
and that of the individual districts



Scale
1 000 000 BARRELS

Compiled by
Chas. A. Ashburner, M.S.
Assistant, Second Geological Survey of Pennsylvania



1858
1860
1862
1864
1866
1868
1870
1872
1874
1876
1878
1880
Oil Creek Division
Pithole Div.
Dec. 6th 1874
Bullion Div
Total production of crude oil in the Oil Fields of Pennsylvania and Southern New York.
Total production 1859 to 1880 inclusive 156.590.311 Bbls.
Warren Division. Warren Co.
448.213 Bbls
Smith's Ferry Division. Beaver Co.
339.631 Bbls.
Harry King Del

STATEMENT OF THE NUMBER OF BARRELS OF OIL PRODUCED FROM AUGUST 26, 1859, TO DECEMBER 31, 1880, BY YEARS AND BY COUNTIES, IN THE OIL REGIONS OF PENNSYLVANIA AND SOUTHERN NEW YORK.

Years.	Number of barrels.	State and county.
Total	156, 153, 807	
1859	1, 000	Venango county, Pennsylvania.
1860	500, 000	Venango, Forest, Crawford, and Warren, Pennsylvania.
1861	2, 113, 609	Do.
1862	2, 056, 690	Do.
1863	2, 611, 309	Do.
1864	2, 116, 109	Do.
1865	2, 497, 700	Venango, with Clarion and Armstrong.
1866	3, 597, 700	Venango, with Cattaraugus county, New York.
1867	3, 347, 300	Do.
1868	3, 715, 700	Do.
1869	4, 215, 100	Do.
1870	5, 659, 000	Venango, with Butler county, Pennsylvania.
1871	5, 202, 710	Do.
1872	5, 985, 635	Do.
1873	9, 882, 010	Venango, with McKean county, Pennsylvania.
1874	10, 920, 435	Do.
1875	8, 788, 470	Do.
1876	8, 952, 355	Do.
1877	13, 129, 780	Do.
1878	15, 159, 180	Do.
1879	19, 741, 755	Do.
1880	25, 960, 260	Do.

TOTAL PRODUCTION OF CRUDE PETROLEUM IN PENNSYLVANIA OIL-FIELDS FROM 1859 TO DECEMBER 31, 1880, BOTH INCLUSIVE, DIVIDED INTO PRODUCING DIVISIONS AND DISTRICTS.

Years.	Oil Creek division.	Pithole district.	Central Allegheny division.	Lower Allegheny division.	Tidioute district.	Clarion division.	Bradford division.	Bullion district.	Warren division.	Beaver division.	Yearly total of all districts.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
Total	35, 517, 217	4, 816, 298	6, 482, 900	37, 342, 978	4, 674, 345	20, 381, 638	44, 574, 921	2, 312, 190	448, 213	339, 631	156, 890, 331
1859	2, 000										2, 000
1860	500, 000										500, 000
1861	2, 113, 609										2, 113, 609
1862	3, 056, 690										3, 056, 690
1863	2, 611, 309										2, 611, 309
1864	2, 116, 109										2, 116, 109
1865	1, 585, 200	912, 500									2, 497, 700
1866	2, 502, 700	1, 095, 000									3, 597, 700
1867	2, 393, 300	954, 000									3, 347, 300
1868	3, 072, 617	547, 500	26, 000								3, 646, 117
1869	3, 762, 500	365, 000	22, 000	45, 000	20, 500						4, 215, 000
1870	3, 039, 528	173, 585	813, 150	918, 644	315, 838						5, 260, 745
1871	2, 040, 263	182, 054	1, 083, 386	1, 091, 458	497, 887	310, 293					5, 205, 341
1872	1, 529, 685	145, 065	881, 140	1, 658, 080	847, 199	829, 079					5, 890, 248
1873	1, 094, 389	119, 864	851, 934	4, 402, 563	895, 983	2, 526, 231					9, 890, 964
1874	734, 247	55, 770	564, 978	5, 160, 265	373, 325	3, 921, 267					10, 809, 852
1875	504, 639	35, 130	343, 905	4, 712, 702	351, 407	2, 821, 214	18, 509				8, 787, 506
1876	611, 884	37, 450	333, 640	4, 755, 623	354, 284	2, 377, 700	382, 768	64, 220	51, 337		8, 968, 906
1877	834, 858	60, 380	474, 262	5, 431, 072	312, 700	3, 012, 120	1, 490, 481	1, 306, 442	151, 371	62, 085	13, 135, 771
1878	686, 948	60, 000	363, 710	4, 552, 815	308, 780	2, 276, 408	6, 208, 746	505, 265	108, 300	92, 490	15, 163, 462
1879	389, 400	36, 500	558, 652	2, 876, 787	227, 900	1, 438, 342	14, 096, 759	289, 591	45, 550	82, 100	20, 041, 581
1880	335, 342	36, 500	166, 143	1, 737, 969	168, 542	868, 984	22, 377, 658	146, 672	91, 655	102, 956	26, 032, 421

RECAPITULATION.

	Barrels.
Oil Creek division, including Shamburg, Pleasantville, and Enterprise	35, 517, 217
Pithole district, including Holderman, Morey, and Ball farms	4, 816, 298
Central Allegheny division, including Scrubgrass to West Hickory	6, 482, 900
Lower Allegheny division, including Butler and Armstrong counties	37, 342, 978
Tidioute district, including Economites, Henderson farm, etc	4, 674, 345
Clarion district, including Clarion county	20, 381, 638
Bradford district, including McKean and Elk counties; also Cattaraugus and Allegany counties, New York	44, 574, 921
Bullion district, including Venango county	2, 312, 190
Warren division, including Stoneham, Clarendon, etc	448, 213
Beaver division, including Smith's Ferry, etc	339, 631
Total production from all districts	156, 890, 331

STATEMENT, BY COUNTIES, OF THE NUMBER OF ACRES DEVELOPED IN THE OIL-FIELDS OF PENNSYLVANIA AND NEW YORK FROM AUGUST 26, 1859, TO DECEMBER 31, 1880.

State and county.	Number of acres.
Total	156, 380
Venango county, Pennsylvania	32, 000
Crawford county, Pennsylvania	6, 400
Forest county, Pennsylvania	1, 920
Warren county, Pennsylvania	6, 720
Armstrong county, Pennsylvania	5, 120
Clarion county, Pennsylvania	19, 200
Butler county, Pennsylvania	27, 520
McKean county, Pennsylvania	50, 000
Cattaraugus county, New York	7, 500

STATEMENT MADE BY THE UNITED PIPE-LINES FROM THE BEGINNING OF APRIL, 1877, TO JULY 9, 1881.

Month.	Gross stocks.	Sediment and surplus.	Net stocks.	Outstanding acceptances.	Credit balances.	Receipts from all sources.	Total deliveries.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
1877.							
April	1, 895, 153. 71	77, 386. 70	1, 817, 767. 01	449, 640. 14	1, 368, 126. 87	200, 570. 81	125, 797. 90
May	1, 762, 602. 64	75, 364. 87	1, 687, 237. 77	683, 663. 71	1, 003, 574. 06	493, 200. 58	619, 612. 26
June	1, 569, 367. 68	81, 255. 42	1, 488, 112. 26	661, 786. 57	826, 325. 69	538, 906. 95	737, 609. 77
July	1, 482, 433. 51	81, 741. 50	1, 400, 692. 01	667, 166. 36	733, 525. 65	615, 145. 46	699, 476. 18
August	1, 489, 052. 53	81, 144. 63	1, 407, 907. 90	643, 281. 46	764, 626. 44	673, 403. 04	666, 144. 28
September	1, 339, 032. 27	67, 163. 68	1, 271, 868. 59	552, 676. 26	719, 192. 33	624, 225. 37	760, 745. 57
October	1, 434, 728. 78	46, 771. 99	1, 387, 956. 79	673, 850. 05	714, 106. 74	687, 094. 59	570, 092. 71
November	1, 691, 399. 52	39, 418. 00	1, 651, 981. 52	657, 591. 36	994, 390. 16	913, 644. 16	649, 242. 70
December	2, 830, 415. 36	68, 729. 63	2, 761, 685. 73	754, 338. 25	2, 007, 347. 48	1, 656, 150. 37	506, 322. 99
1878.							
January	3, 124, 641. 15	72, 453. 43	3, 052, 187. 72	864, 711. 41	2, 187, 476. 31	972, 681. 18	715, 149. 78
February	3, 439, 526. 98	82, 452. 66	3, 357, 074. 32	1, 404, 292. 13	1, 952, 782. 19	1, 030, 688. 44	720, 478. 14
March	3, 940, 000. 65	92, 963. 06	3, 847, 037. 59	1, 487, 439. 50	2, 359, 598. 09	1, 196, 251. 26	701, 681. 27
April	4, 335, 274. 84	133, 934. 76	4, 201, 340. 08	1, 615, 791. 19	2, 585, 548. 89	1, 137, 359. 40	778, 050. 53
May	4, 609, 681. 45	150, 117. 76	4, 459, 563. 69	2, 065, 333. 31	2, 394, 230. 38	1, 104, 352. 40	843, 081. 33
June	4, 719, 699. 25	181, 800. 03	4, 537, 899. 22	1, 950, 420. 81	2, 587, 478. 41	1, 092, 604. 02	1, 004, 474. 55
July	4, 885, 851. 72	229, 080. 78	4, 656, 770. 94	2, 078, 469. 56	2, 578, 301. 38	1, 258, 648. 45	1, 108, 074. 33
August	4, 571, 658. 59	217, 085. 19	4, 354, 573. 40	2, 064, 590. 76	2, 289, 982. 64	1, 195, 268. 67	1, 496, 009. 04
September	4, 410, 061. 84	225, 088. 86	4, 184, 972. 98	1, 705, 853. 95	2, 479, 119. 03	1, 182, 118. 57	1, 318, 265. 33
October	4, 072, 627. 43	234, 050. 89	3, 838, 576. 54	1, 517, 484. 27	2, 321, 092. 27	1, 271, 174. 73	1, 564, 984. 43
November	4, 083, 972. 42	216, 655. 30	3, 867, 317. 12	1, 784, 443. 35	2, 082, 873. 77	1, 159, 623. 71	1, 129, 047. 02
December	4, 098, 200. 92	201, 470. 30	3, 896, 730. 62	1, 741, 311. 07	2, 155, 419. 55	972, 338. 83	924, 035. 93
1879.							
January	4, 759, 031. 41	182, 707. 80	4, 576, 323. 61	2, 153, 763. 83	2, 422, 559. 78	1, 231, 237. 19	546, 271. 74
February	5, 157, 646. 15	171, 689. 80	4, 985, 956. 35	2, 346, 238. 22	2, 639, 718. 13	1, 055, 377. 95	633, 828. 71
March	5, 503, 768. 71	190, 797. 91	5, 312, 970. 80	2, 484, 881. 83	2, 828, 088. 97	1, 363, 512. 17	1, 029, 029. 70
April	5, 885, 675. 24	211, 957. 06	5, 673, 718. 18	2, 644, 301. 36	3, 029, 416. 82	1, 379, 349. 76	1, 015, 482. 04
May	6, 180, 843. 53	315, 992. 98	5, 864, 850. 55	2, 522, 486. 36	3, 342, 364. 19	1, 488, 514. 31	1, 228, 043. 27
June	6, 426, 802. 45	334, 457. 29	6, 092, 345. 16	2, 959, 921. 12	3, 132, 424. 04	1, 437, 250. 90	1, 204, 757. 54
July	6, 419, 699. 08	323, 295. 32	6, 096, 403. 76	3, 323, 575. 29	2, 772, 828. 47	1, 472, 651. 01	1, 465, 518. 05
August	6, 380, 606. 63	302, 345. 15	6, 078, 261. 48	3, 581, 224. 03	2, 497, 037. 45	1, 714, 620. 11	1, 728, 940. 81
September	6, 589, 859. 83	325, 363. 85	6, 264, 495. 98	3, 783, 480. 38	2, 481, 015. 60	1, 691, 863. 41	1, 455, 811. 45
October	6, 701, 209. 87	299, 393. 67	6, 401, 816. 20	3, 788, 155. 65	2, 613, 660. 55	1, 646, 725. 06	1, 502, 991. 20
November	6, 951, 133. 67	303, 641. 17	6, 647, 492. 50	3, 972, 300. 18	2, 675, 192. 32	1, 600, 961. 29	1, 328, 621. 19
December	7, 362, 409. 76	294, 571. 37	7, 067, 838. 39	4, 235, 459. 40	2, 832, 378. 99	1, 771, 781. 24	1, 331, 822. 12
1880.							
January	7, 735, 257. 38	295, 517. 60	7, 439, 739. 78	4, 436, 788. 55	3, 002, 951. 23	1, 832, 963. 04	1, 455, 194. 98
February	8, 187, 012. 49	322, 568. 93	7, 864, 443. 56	4, 602, 286. 49	3, 262, 157. 07	1, 607, 663. 89	1, 178, 111. 92
March	8, 621, 097. 49	351, 130. 35	8, 269, 967. 14	4, 811, 894. 33	3, 458, 072. 81	1, 815, 133. 31	1, 396, 037. 88
April	9, 662, 354. 59	388, 558. 16	9, 273, 796. 43	5, 846, 536. 60	3, 427, 259. 83	1, 739, 297. 37	723, 794. 73
May	10, 306, 078. 79	454, 193. 73	9, 851, 885. 06	6, 361, 320. 05	3, 490, 565. 01	1, 552, 240. 91	975, 061. 26
June	11, 266, 771. 77	477, 431. 69	10, 789, 340. 08	7, 397, 131. 89	3, 392, 208. 19	1, 781, 937. 29	848, 339. 08
July	12, 039, 010. 00	475, 446. 56	11, 563, 563. 44	8, 125, 241. 25	3, 438, 322. 19	1, 890, 161. 44	1, 095, 528. 25
August	12, 749, 623. 28	462, 987. 28	12, 286, 636. 00	8, 635, 394. 80	3, 651, 241. 20	1, 904, 452. 70	1, 177, 448. 42
September	13, 618, 726. 03	382, 398. 71	13, 236, 327. 32	9, 287, 193. 94	3, 949, 133. 38	2, 075, 105. 26	1, 115, 184. 71
October	14, 020, 877. 39	391, 331. 55	13, 629, 545. 84	9, 448, 615. 77	4, 180, 930. 07	1, 999, 487. 98	1, 498, 285. 06
November	14, 656, 891. 55	341, 262. 67	14, 315, 628. 88	10, 083, 824. 08	4, 231, 804. 80	1, 859, 991. 50	1, 064, 146. 39
December	15, 369, 758. 67	361, 184. 83	15, 008, 573. 84	10, 913, 283. 49	4, 095, 290. 35	1, 987, 283. 54	1, 207, 928. 35
1881.							
January	16, 291, 307. 87	360, 688. 98	15, 930, 618. 89	11, 672, 583. 61	4, 258, 035. 28	1, 876, 526. 50	931, 718. 71
February	17, 355, 485. 31	391, 616. 47	16, 963, 868. 84	12, 029, 594. 35	4, 934, 274. 49	1, 823, 713. 46	781, 747. 93
March	18, 488, 476. 94	432, 304. 19	18, 056, 172. 75	13, 099, 262. 44	4, 956, 910. 31	2, 222, 812. 39	1, 116, 695. 11
April	19, 560, 752. 23	517, 422. 38	19, 043, 329. 85	13, 846, 285. 20	5, 197, 044. 65	2, 182, 636. 96	1, 183, 779. 02
May	20, 591, 117. 33	640, 662. 03	19, 950, 455. 30	14, 608, 124. 70	5, 342, 330. 60	2, 278, 582. 78	1, 356, 688. 23
June	21, 397, 698. 53	756, 412. 85	20, 641, 285. 68	14, 738, 828. 77	5, 902, 456. 91	2, 318, 445. 18	1, 545, 448. 13

The above figures are in barrels of forty-two gallons each.

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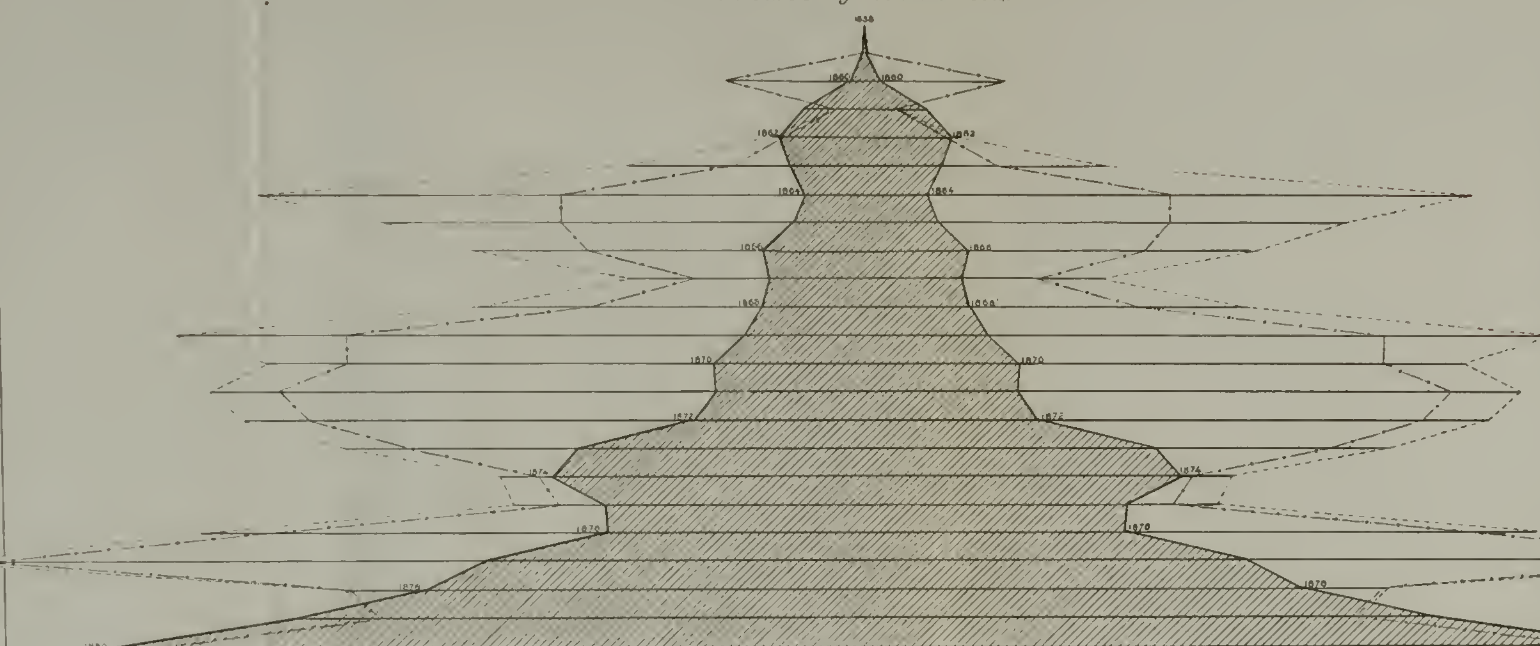
CHART
Nº 3.
Showing the annual production of **Petroleum**
IN THE OIL REGION
of Pennsylvania and Southern New York
Since its discovery, with the values of the production in Currency and in Gold.

Year	Average yearly price	Total annual value of production in Greenbacks
1859	20 00	40 000.00
1860	9.60	4 800 000 00
186[illegible]	.49	1 035 668 [illegible]
1862	1.05	3 209 524 50
1863	3.15	8 225.625.35
1864	9 87½	20.896 576.37
1865	6.59	18.459 845 00
1866	3.74	[illegible]3 455 398 00
[illegible]867	2.41	8.066 993 00
1868	3.62½	13.217 174 12
1869	5 63	23 730 450 00
1870	3.89½	20.50[illegible] 753 64
[illegible]871	4.34	22 [illegible] 179 94
[illegible]872	3.64	21 [illegible] 302 72
1873	[illegible]83	8.10[illegible] 484 12
[illegible]874	1 17	12 647 526 84
1875	[illegible]35	[illegible] 33 10
1876	2 56½	22.982 821 82
[illegible]877	2.42	31 788 323 82
1878	1. [illegible]9	[illegible] 78
1879	[illegible]85½	[illegible] 953 15[illegible] 35
1880	94½	24 [illegible]00 637 94
	TOTAL	324 920.265 55



Notes.

Drake well, the pioneer well in Pennsylvania, "struck oil" August 28th 1859

October to December 1861, average monthly price of crude oil, 10 cts a barrel, minimum value

January 1862, gold at a premium.

Oil field supposed to be defined, hence price of oil rises rapidly.

Pithole Division commenced to produce.

Gold at the maximum premium during 1865

Maximum production of Pithole Division

Central Allegheny Div commenced to produce

Tidioute, Butler & Armstrong Divs commenced to produce.

Maximum production of Oil Creek Division.

Clarion Division commenced to produce.

Maximum production of Central Allegheny Div.

Maximum production of Tidioute Division

Bradford Oil Sand discovered December 6th 1874.

Bullion and Warren Divisions commenced to produce

Beaver Division commenced to produce.

Maximum total value of 31 788.323 dollars attained.

Price of oil falls rapidly in consequence of the unparalleled growth of the Bradford field

January 1st 1879 specie payments resumed in the U.S.

Maximum monthly average [493] of drilling wells attained

Legend

Value of total production in Greenbacks
Value of total production in Gold.
Total production of entire region.

Scale

1 000 000 2 000 000 4 000 000 6 000 000 8 000 000 10 000 000 BARRELS OR DOLLARS

Notes.

The total annual value was obtained by multiplying the total production by the average yearly price
The average yearly premium on gold was obtained by taking an average of the highest, lowest, opening and closing price of gold in currency for each month in each year

Compiled by
Chas. A Ashburner M.S.
Assistant, Second Geological Survey of Pennsylvania.

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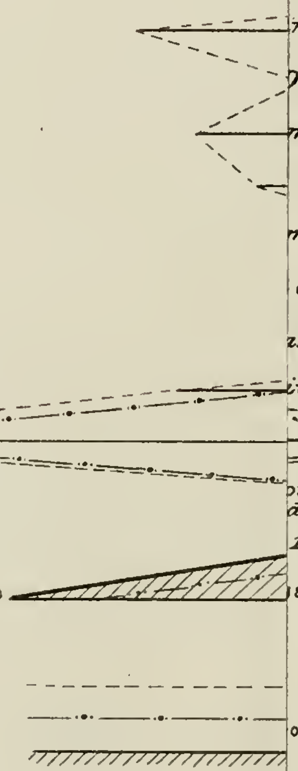
Year	Average yearly price	Total annual value of production in Greenbacks
1859	20.00	40.000.00
1860	9.60	4.800.000.00
1861	.49	1.035 668.41
1862	1.05	3.209.524.50
1863	3.15	8.225.623.35
1864	9.87½	20.896.576.37
1865	6.59	16.459.843.00
1866	3.74	13.455.398.00
1867	2.41	8.066.993.00
1868	3.62½	13.217.174.12
1869	5.63	23.730.450.00
1870	3.89¾	20.503.753.64
1871	4.34	22.591.179.94
1872	3.64	21.440.502.72
1873	1.83	18.100.464.12
1874	1.17	12.647.526.84
1875	1.35	12.133.133.10
1876	2.56½	22.982.821.62
1877	2.42	31.788.323.82
1878	1.19	18.044.519.78
1879	.85¾	16.953.151.38
1880	.94½	24.600.637.84
	TOTAL	$324.920.265.55



Notes.

ll. the pioneer well in Pennsylvania, il" August 28th 1859.

to December 1861, average monthly ude oil .10 cts a barrel, minimum value.

1862, gold at a premium.

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Division commenced to produce.

the maximum premium during 1865

m production of Pithole Division.

Allegheny Div. commenced to produce.

ller & Armstrong Divs. commenced to produce.

m production of Oil Creek Division.

Division commenced to produce.

m production of Central Allegheny Div.

m production of Tidioute Division.

Oil Sand discovered, December 6th 1874.

and Warren Divisions commenced to produc

ivision commenced to produce.

Maximum total value of 31.788.323 dollars attained.

oil falls rapidly in consequence of the un- d growth of the Bradford field.

1st 1879 specie payments resumed in the U.S.

Maximum monthly average [495] of drilling wells attained.

Harry King Del.

MISCELLANEOUS PIPE-LINE STATISTICS FOR 1879 AND 1880.

Month.	Daily average of charters.		Average daily runs by all lines.		Stocks in pipe-line tanks.		Tide-water.			
							Runs.		Shipments.	
	1879.	1880.	1879.	1880.	1879.	1880.	1879.	1880.	1879.	1880.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
Average for the census year...	32,377	....	61,837	....	8,323,681	....	203,378	....	179,409	....
January	14,800	18,303	45,719	67,330	5,064,693	8,520,696	65,026	154,034	216	118,400
February	12,200	20,822	43,105	62,671	5,541,683	8,930,508	52,182	125,376	492	716,057
March	27,700	18,954	48,856	67,024	5,928,628	9,369,240	55,421	167,564	37	741,062
April	26,000	18,975	50,754	67,921	6,332,841	10,545,425	53,477	199,327	2,585	34,162
May	32,800	18,370	52,963	59,048	6,565,454	11,230,883	55,489	905,153	36,728	88,836
June	49,000	36,735	53,908	69,931	6,849,389	12,281,711	82,035	230,089	35,575	94,398
July	36,000	35,033	54,061	71,072	6,938,690	13,150,974	108,020	210,178	24,588	94,095
August	38,600	30,916	61,886	71,010	6,998,046	13,945,113	107,402	196,249	40,680	85,482
September	47,300	33,567	63,504	67,813	7,328,980	14,713,346	121,303	169,147	58,054	97,493
October	44,700	18,231	60,694	70,861	7,402,630	15,114,802	139,883	185,551	98,889	129,178
November	46,300	21,730	60,278	65,799	7,675,193	16,756,954	118,092	162,269	97,366	121,978
December	31,300	21,500	63,722	57,749	8,094,496	16,616,628	114,352	173,125	99,243	110,659

SECTION 8.—THE PRODUCTION OF THE PACIFIC COAST.

Concerning the petroleum production of the Pacific coast, I have to say that I have no official returns from any of the parties interested, no communication addressed to them having elicited any response whatever, and in consequence I have been forced to rely on such other sources of information as were available. My own experience in relation to the petroleum of that region led me to accept all reports published in the newspapers with great caution I addressed a letter of inquiry to the senior member of a firm long engaged in trade in refined oils upon the San Francisco market, and received the following reply, dated March 16, 1882:

The consumption of this coast of eastern oils is 4,500,000 gallons of refined. The product of all the refineries of this coast does not exceed 400,000 gallons refined. It is of inferior quality, low test, and is principally sold to the Chinese trade at about 16 cents per gallon in cans, or less, by 6 cents per gallon, than the cheapest eastern oils. In addition, about 400,000 gallons of crude oil is sold here for making gas and fuel. The production seems to be decreasing, the wells being, as a rule, short-lived. The above is, I consider, reliable, and is the best information I can get. My firm sell considerable oil, both high- and low-test eastern. We have no demand for California production.

Mr. J. C. Welch, in his report for February, 1880, says:

My California correspondent writes, February 2, as follows: "In reference to the Californian production, I would state that since my last letter there has nothing new been developed. It is very expensive and very difficult to drill wells in California, owing to the angle at which the rock stands, causing it to cave from the top to the bottom of the well. It requires four or five sizes of casing, telescoped from 12 inches to the smallest size that can be drilled through. In this way it requires about as much capital to case a well here as the entire expense of a well in Pennsylvania. The time required to drill is from three months to two years, it being very difficult to get the casing down, the rock caving at every point. However, these obstacles would all be overcome if there was a class of men like Pennsylvania producers in this country to drill wells, but, fortunately for the producing interests of the United States, the monopoly in California is in the producing interest instead of in the refining and transportation interest, as in Pennsylvania. A syndicate of millionaires, led by C. N. Felton (who was first in the development of the Bonanza mines of Nevada), have been busily engaged for the last two years in purchasing in fee all the lands that show any indications of being oil territory, which, as the tracts of land in which the oil district is located were originally divided by the old Spanish grants containing hundreds of thousands of acres, it has been a comparatively easy matter for them to do, and they seem inclined to keep their oil in the ground until such times as Pennsylvania shall have exhausted her supplies and the product here is needed for the world's demand. Although the same company have obtained all the necessary machinery, iron, and fixtures for the refinery (of which I wrote you recently), and have land secured in a favorable location, located on the bay and also connected with both systems of railroad, narrow and broad gauge, yet they have not actually commenced the erection of the works. It will require about ninety days from the time they break ground until the refinery can be completed.

As I suggested in my former letter to you, these parties at present do not intend to produce more oil than is required for the Pacific coast trade, and for the next two or three years the California territory need have no influence whatever on the general petroleum market unless some unexpected strike should be made that now seems unlikely, as there are only two or three wells being drilled.

I do not know exactly what percentage of refined oil is obtained from California crude; but should not, from my experience, place the production at above 1,000,000 gallons, or 2,500 barrels.

SECTION 9.—THE FOREIGN PRODUCTION OF PETROLEUM IN COMPETITION WITH THE UNITED STATES.

From various reports that have received my attention in reference to this subject I select the following as most entitled to confidence. The first which I offer, reviewing all of the European fields upon observations made during the census year, is from the February (1880) report of Mr. J. C. Welch. The second paper was prepared expressly for this report by William Brough, esq., of Franklin, Pennsylvania, a gentleman of large experience in the Pennsylvania oil regions, whose opinions are based upon a careful personal inspection of the Russian petroleum fields, they being really the only European fields likely to prove of more than local importance. Mr. Welch, in his report on Russia, says:

The various oil territories of the world have, during the past year, been receiving some attention, and the chance of their supplying oil to meet more or less of the world's needs is of course an important one to those whose interests are principally identified with that

supply being drawn from western Pennsylvania. The Russian territory on the Caspian sea has received the most attention, and it has a prolific yield; the two things that have militated chiefly against its being a competitor of importance of the Pennsylvania petroleum are in the character of the oil, only yielding about 33 per cent. of illuminating oil, and in the difficulty of getting it to the markets of the world through inadequate means of transportation. The opinion prevails among some that a percentage of illuminating oil can be got from it as great as that obtained from American petroleum, requiring, however, some different process of refining. This plan is to be tested soon by the erection of a refinery in Russia, the owners having sufficient confidence in their process to erect a refinery of sufficient size to be a complete test as to whether the process will be a success or not.

Mr. L. Emery, jr., a well-known resident and producer of this region, has just returned from the Baku field, after having taken time to give it a critical examination. He estimates the production there during the past year to have been about 28,000 American barrels per day from 78 wells, showing the extraordinary average of 360 barrels. The depth of the wells is only about 500 feet. There were shipped from Baku last season about 1,230,000 gallons of refined oil. Oil is refined at Baku at 195 refineries, with a charging capacity of 28,000 American barrels. There are now in course of erection stills with a charging capacity of about 2,000 barrels, which will be ready for business with the opening of navigation in the spring. Some of these refineries are very small; others are owned by independent corporations with large capital. From Baku oil is sent east, south, and west by canals and wagons, and by the Volga river to Kisan, and thence by cars it reaches the principal markets of Russia.

Mr. Emery says it is estimated there are 25,000,000 poods (about 3,125,000 barrels) of crude oil in the vicinity of Baku held in excavations in the ground or lakes. Pipe-lines are being used from the wells to the refineries in the vicinity of Baku, a distance of 6 miles. Two 3-inch lines have recently been laid, one with pipes of American and one of English manufacture; and three more pipe-lines are in process of construction, one of 5 inches diameter, the other two of 3 inches diameter. A railroad also runs through the district. The price paid for pipeage is about 8 cents per American barrel, and oil is now a drug at 6 cents a barrel at the wells.

Petroleum is found more or less on both sides of the Caucasian mountains; and oil is produced within the city limits of Tiflis, a city which is rated by the latest census as having 70,591 inhabitants. A railroad is in operation from the Black sea to Tiflis, a distance of 180 miles, and is in process of construction from Tiflis to Baku. Eighteen miles of this is already built, its construction having commenced last summer. The contract calls for its completion within three years of its commencement, with a forfeiture for every day over that time that it is not completed The contractor, however, states his expectation of completing the road within eighteen months from the beginning. The Russian government is the chief mover in the construction of the road, and the road is being built by a government contractor of large means.

In this railroad, and in the possibility of a process of refining oil by which an increased percentage of illuminating oil can be eliminated, rests an apparent danger to the petroleum business of western Pennsylvania. With this railroad completed the Baku oil would be placed on tide-water navigation with a railroad haul of nearly 600 miles. The commerce of the Black sea is already very important, Odessa, located upon it, being one of the great grain markets of the world.

Very considerable attention is now being turned toward territory in Europe that presents some aspects of being oil-bearing. The country south of the Caucasian mountains, of which Tiflis is the center, while belonging to Russia, is in Asia. Immediately north of the Caucasian mountains is the Kouban river, emptying into the Black sea.

The following is from my New York daily report of March 12:

"I have recently come more fully in contact with people having knowledge of the oil-producing territory on the Caspian sea than I had at the time of writing my February monthly report, and I now find the statement I made in that report is of much too favorable a character in regard to Baku production and getting the Baku oil to market. The railroad I spoke of as being constructed between the Black and Caspian seas has been constructed for some time from the Black sea to Tiflis, and a short piece has been built, say 12 miles long, on the Baku end, in the vicinity of the oil-wells. It is intended to go to work on the road east of Tiflis soon, but operations have not yet commenced, or had not recently. This distance is between 300 and 400 miles, and there are some uncertainties concerning its construction which may keep it delayed for a long time. I am informed by merchants in this city, who have correspondents in that vicinity, that my information is at fault very considerably regarding the amount of production at Baku, and that it is very much less. Taking into consideration what I am recently informed, the matters at Baku are not of a nature, I judge, that require them at present to be taken into account as having a bearing upon the prices of American petroleum."

Dr. Tweddle, formerly of Pittsburgh and Franklin, representing a French company, is drilling two wells upon this river, and has a small refinery at Taman, a city located near the mouth of the Kouban. He has secured enormous tracts of territory from the Russian government. Five drillers and experienced well-men recently left Oil City to join Dr. Tweddle on the Kouban river. Mr. James R. Adams, of Oil City, experienced in oil matters, has been with Dr. Tweddle since last summer, having previously spent a year at Baku.

The following is Mr. Welch's report on Galicia and Germany:

Galicia, in Austria, has been producing some oil for a considerable time, and has now a production of about 500 barrels per day. This territory has been visited by Americans accustomed to drilling wells and refining oil, who had gone to inspect it, with a view of doing business there, and they came away unfavorably impressed with it as a place to locate in the oil business. Drilling is difficult and expensive there, the strata of the rocks not lying horizontally, but being at an angle that causes them to cave after being drilled through. Much or most of the oil is taken from near the surface from wells dug down, and the oil then bailed out. The oil is unreliable in gravity even at considerable depths, and the heavier grades are a drug, not being treated in such a way as to make a satisfactory lubricating oil. The Galician field is situated on the north side of the Carpathian mountains, and extends a distance of about 200 miles, with a width of about 10 miles. In Hungary, on the south side of the Carpathian mountains, there are the same indications of oil that there are on the north side. An English-American company has secured 29 square miles here, and are now taking steps to operate it.

There have been numerous cable reports published in the newspapers recently of oil discovered in Hanover, Germany. European petroleum circulars I have received since these reports were circulated make no mention of them, and I have as yet heard nothing from my European correspondents upon the subject, although I cabled Bremen about it, and it consequently appears to me that the European petroleum trade is not taking much notice of these reports.

Some petroleum has been found not far from Bremen for the past two hundred years. While I was in Bremen one year ago I took some notes of what gentlemen I met hoped would prove to be an oil district. It is located 128 English miles southeast of Bremen. They had three wells then down, of different depths, as follows: 181, 242, and 680 feet. Of the first two they were getting a small quantity of oil, one yielding 5 and the other 30 per cent. of illuminating oil. The other well they were then beginning to test. I am informed since that it only produces a barrel and a quarter per day, and that it is of heavy gravity. These wells are near the small city of Peine. Wells recently cabled about to the newspapers are near Heide, in the northwestern portion of Holstein.

The following is William Brough's description of the Russian oil-belt:

The Russian "oil belt" may be traced, at intervals more or less remote, from the island of Schily-Khany, near the eastern shore of the Caspian sea, westward over the promontory of Apscheron, and following the line of the Caucasian mountains into the valley of the river Kouban, which empties its waters through a lagoon into the Black sea; thence it may be traced in the same general direction across the Crimea and to the oil-fields of Galicia, in Austria. This belt is actively worked in the Crimea, in the valley of the Kouban, and on the promontory of Apscheron, near the city of Baku; it is only at the latter point, however, that the product is sufficiently large to induce the gathering of statistics. At all other points the petroleum produced, whether gathered from springs or obtained by well-boring, is entirely absorbed by local consumption.

The following table gives the shipments of petroleum and its products from Baku for the years named, in barrels of forty gallons each:

Year.	Refined.	Residuum.	Crude.
1876	392, 977	150, 021	22, 137
1877	561, 236	232, 782	17, 169
1878	750, 218	388, 042	24, 699
1879	828, 347	755, 688	38, 628
1880, to July 1	376, 736	427, 953	24, 470

As the average yield of refined petroleum from Apscheron crude is about one-third, we may estimate the total crude product of that field for the year 1879 at 2,500,000 barrels, or 6,850 barrels per day. This oil is all consumed in Russia, a very little manufactured for lubricating excepted. The residuum is used for fuel, and is consumed nearly altogether by the steam vessels on the Caspian sea and the Volga river.

As shown by the table, the product of the Apscheron field declined about 9 per cent. in the first half of the year 1880, and by the end of that year the decline was so serious that the price, which had ruled for two years with little variation at 24 cents per barrel, advanced in the autumn to between $1 and $2 per barrel; but in 1881 production was so increased that in August the price had fallen to 2 copecks per pood for oil at the wells, equal to 8 cents per barrel of 40 gallons.

The Apscheron oil-field as at present worked lies within a radius of 20 miles of the city of Baku, but nine-tenths of the total product has so far been obtained from the deposit at Balachany, which covers an area of from 2,000 to 3,000 acres. This deposit has proved very rich. The oil is found in a loose, open sand, at a depth varying from 120 to 450 feet, and is brought to the surface in balers having check-valves in the bottom similar to the sand-pump used in the Pennsylvanian oil regions, the large amount of loose sand which comes up with the oil preventing the use of the ordinary suction-valve pump used in American wells. The largest well ever found in the Balachany district had been producing for six years in 1879, and had yielded during that time an average of 1,200 barrels per day—a production much in excess of that of any Pennsylvanian well. The diameter of the wells is from 8 to 12 inches; the capacity of the balers from 20 to 40 gallons. There are about 400 wells in the entire Apscheron district, the largest outside of Balachany giving about 10 barrels per day, and the average yield of the whole number, including Balachany, being about 20 barrels per day.

Balachany is situated 12 miles north of Baku, and is connected with it by a railway. There are also two pipe-lines for the transportation of oil to the latter place, where the refineries are mainly situated, and which is the port of shipment. There is one other pipe-line from Balachany to Soorachany, 5 or 6 miles distant, and 10 miles northeast of Baku. At Soorachany a large refinery is located, in order to utilize as fuel the gas from gas-springs there; there, too, may still be seen an ancient temple of the fire-worshipers, where prayers are daily said to a jet of petroleum gas, whose flame is never permitted to expire.

The development of the Apscheron oil-field has constantly been restricted by want of transportation facilities, the only outlet for the production from Baku to the markets of Russia being by way of the Caspian sea and the Volga river. Beside this new business of petroleum, now thirteen years established, the general commerce of the Caspian has in the same time been steadily growing, and the number of sea-going vessels, though constantly increasing, is still quite inadequate to supply the demand for transportation. In 1878 there were 30 steamships plying this sea; and of these 12 were imperial, leaving 18 merchant ships, varying in size from 300 to 500 tons. Eleven more were added in 1879, making 29 merchant steamships in all. There are beside numerous sailing-vessels. The steamships are all of foreign build, mainly English, and having to pass through the canals connecting the Baltic with the Volga, their size is consequently limited thereby. Some of them have been floated through in two sections. As the depth of water in the delta of the Volga is ordinarily but 2 feet, it is only in the spring of the year, when the water is 9 feet deep there, that these vessels can enter the Caspian. The oil, both crude and refined, is conveyed by these vessels in bulk compartments, as well as in casks and barrels, steamers being used almost exclusively for refined and sailing-vessels for crude and for residuum. The voyage is made from Baku to "nine-foot" water, where the vessels anchor in open roads and deliver their cargoes to barges built expressly for the shallow waters of the delta. These barges convey the oil to Astrakhan, a distance of 330 miles.

At Tzaritzin the facilities for unloading the barges, for storing oil, or delivering it to the railroad are modern in character, and are really copied from the American methods. They consist of pipes, pumps, and large iron storage-tanks. The railroad also is equipped with iron tank-cars similar to the American. Farther up the Volga the railway again connects with the river at Saratov, at Syzran, and at Nijni-Novgorod, to all of which oil is shipped, the last named being the most northerly point of river shipment, and 1,400 miles from Astrakhan.

In January, 1880, the Russian government granted a concession for the building of a railroad between Baku and Tiflis, the capital of the Caucasus, which was already connected by rail with Poti, on the Black sea. When this road shall be completed, it will furnish an outlet for Baku oil to the markets of Europe, and will bring it into direct competition with American oil in those markets The work of building this road is, if measured by the Russian standard, progressing rapidly. In August, 1881, 120 versts (about 80 miles) between Baku and Adji-Kabul was finished and in running order, and it is expected that the whole road will be completed by August, 1882. Its oil-car equipment will have capacity to deliver at the Black sea 1,000,000 barrels per year. As the harbor of Poti is exposed and unsafe, the railway will be extended 60 miles farther south to Batoum, recently ceded by Turkey to Russia, and the best harbor on the Black sea. The whole length of the railway will be 660 miles. The freight rate is uniform on all the railroads of Russia, being prescribed by the imperial government, and in 1879 was for petroleum 1 copeck per pood for 45 versts, or 9¼ mills for carrying one ton of 2,000 pounds 1 mile. At this rate the cost of transferring a barrel of petroleum from Baku to Batoum will be 88 cents.

As the petroleum product of Apscheron has thus far been so steadily maintained above the carrying capacity of the vessels on the Caspian sea, we need not doubt that, with the opening of the Baku and Tiflis railroad, other deposits will be found along the line indicated. Indeed, the Russian oil man is fully alive to this conception, and is already prospecting along the whole line from Baku to Adji-Kabul, buying and selling, leasing and releasing, oil lands after the manner of his American prototype. But until this railroad is completed the Americans need not fear competition from that quarter. The high rates of freight on the Caspian, the delays and hazard

attending the discharge of cargo in open sea at "Nine-foot", the double transfer, and the long voyage from "Nine-foot" to Tzaritzin, requiring the service of steam-tugs all the way, these, added to the fact that this only outlet is closed by ice from November until April, form a complete bar to such competition. Indeed, it is doubtful whether the Russian could now hold his place in his own market without the help of the duty imposed for his protection upon American petroleum. This duty is 9 cents per gallon, payable in gold.

The gravity of Baku oil ranges from 26° to 36° B., there being very little of the latter grade, and the gravity of oil taken from pipe-line tanks, where the product of different wells is mixed, is about 30° B. This mixed oil gives a yield of 33 per cent. illuminating oil, and the residuum is used for fuel. No other fuel is used by steamers on the Caspian sea. Many of the steamers on the Volga also use it. It is also the only fuel used by the locomotives on the railway now building and partly completed from the eastern shore of the Caspian sea into the Turkoman territory recently acquired by Russia.

The oil-fields of the Kouban valley and the peninsula of the Taman, on the Black sea, have been worked actively, with some intervals of comparative rest, since 1864. In that year a Russian nobleman, Count Novosiltzoff, leased 1,500,000 acres from the "Cossacks of the Kouban" and began operations on an extensive scale. He employed American workmen, and extended his well-drilling over a stretch of country 150 miles in length. He also built a large refinery at Taman, on the straits of Enikale, near the western end of his territory. It is difficult now to ascertain what success attended his operations. At one point, Kudokko, it is said he obtained a very large well, some Cossack estimates putting it at 10,000 barrels per day; but we may rest assured that this is a greatly exaggerated statement. It may be doubted whether the well produced at any time 1,000 barrels per day, or for any considerable time even a hundred, for Novosiltzoff failed to obtain oil enough from his wells to compensate him for his expenditures, notwithstanding that the price ruled very much higher then than now; and his enterprise finally failed, after sinking his original capital and involving him in an indebtedness of about 1,500,000 rubles. The Kudokko well is still producing; its yield in 1878 was about 23 barrels per day. The well was then four years old. It is pumped by steam-power, with a suction-valve pump. The oil is of good quality, olive-green in color, gravity 36° B., and yields when distilled 50 per cent. of illuminating oil. A small refinery on the estate works up the oil into lubricants and illuminants, and finds ready sale for the entire product in the Cossack community of the neighborhood. Twenty-eight other wells were drilled around this first well without increasing the total product; indeed, the Kudokko oil-field has been shrinking steadily since it was first opened, notwithstanding the occasional drilling of new wells, and its total product is now less than 20 barrels per day.

In 1879 a French company, under American management, leased all the Novosiltzoff land except the 25,000 acres which form the Kudokko estate, and began operations in a vigorous manner. This company is still at work; it has in its employ skilled, practical workmen from the oil regions of Pennsylvania, and it has made several large shipments of well machinery from America. It also recently purchased here pipe and pumps for a pipe-line from Ilsky, where its most productive wells are situated, to the port of Novorossisk, on the Black sea, 65 miles west of Ilsky. It is perhaps too soon to determine what success in finding oil will attend its operations; but the total yield of its wells is thus far about 80 barrels per day, and the greater part of this product is of inferior character, being a black bituminous oil. It may, however, be doubted whether any large deposit of petroleum will ever be formed within the limits of this field, taking Ilsky as its eastern boundary and including all the land westward which forms the peninsula of Taman, bounded on the north by the sea of Azov and the straits of Enikale and on the south by the Black sea. There has been a large amount of unsuccessful test-drilling done here in the last sixteen years, but no rock has yet been found which makes a suitable receptacle for petroleum. Wherever found, the oil is diffused through the whole strata of soil and near the surface, so that no mechanical ingenuity is required to reach it, but it can be obtained with the rudest well-boring implements. It is therefore reasonable to conclude that the country has been worked for oil from remote times.

The greatest depth at which oil has been found here is 400 feet, and deeper drilling has thus far given no promise of success. These remarks are equally applicable to the Crimean district, which is of the same character.

Although illuminating oils manufactured in Russia from the native crude product compare favorably with the American oils, the latter have nevertheless been yearly imported into Russia, though in diminishing quantity; but the fact that these imports still continue seems to need some explanation, in view of the heavy duty of 9 cents per gallon imposed on American oil. A comparison of the burning qualities of the two oils shows that the American gives a slightly whiter flame, and that it is less liable to smoke than the Russian. In odor and color they are equal. The Russian oil burns with undiminished flame until the oil in the lamp is exhausted, while the flame of the American sinks when the oil becomes low in the lamps. The fire-test of the Russian oil is quite as good as of the best American, and the tendency to smoke of the Russian is easily overcome by a proper adjustment of the lamp-chimney.

The Russians have lately introduced some new patterns of chimneys.

These remarks apply only to standard oils of both countries found in open market at St. Petersburg, rejecting special brands and inferior or defective lots.

The following table gives the imports of American refined petroleum into Russia for the years named, the figures being taken from Russian official records and transposed from "poods" into barrels of forty gallons each:

	Barrels.		Barrels.		Barrels.
1867	68,316	1872	203,901	1877	261,780
1868	111,424	1873	379,481	1878	251,227
1869	158,137	1874	310,981	1879	188,752
1870	198,386	1875	308,225	1880	143,154
1871	217,555	1876	277,671		

In conversation with Mr. Charles H. Trask, of the firm of William Ropes & Co., of 70 Wall street, New York, largely engaged in the Russian trade, he remarked that transportation from Baku to St. Petersburg was so expensive that a high gold duty, augmented by a depreciated currency, alone rendered the manufacture of Russian oils in St. Petersburg possible. Without this duty the oils could not compete with American, although the lubricating oils made from Russian crude do not chill and are superior to American lubricating oils. He said, further, that shipments of low-grade American oils to Russia had entirely ceased, but that high-test American oils were still sold there. As the tariff may be changed at any time, the business was somewhat uncertain both for those within and those outside Russia.

I have not been able to obtain any satisfactory statistics of the Canadian production. So far as I can learn, stocks had accumulated in Canada before 1879, but during that year and subsequently these stocks were drawn down, so that the production of refined during the census year was no indication of the production out of the ground. I have not therefore made any attempt to estimate the Canadian production, which is only of local importance, as partially supplying the Dominion markets.

PART II.

THE TECHNOLOGY OF PETROLEUM.

PART II.

Chapter I.—MIXTURES OF PETROLEUM.

Section 1.—FILTERED PETROLEUM.

Petroleum was prepared for use, particularly in medicine, by filtering, at a very early date in southern Ohio Dr. Hildreth, as early as 1833, (*a*) mentions filtering petroleum through charcoal, by which much of its "empyreumatic smell is destroyed and the oil greatly improved in quality and appearance". Since that time petroleum has been filtered through gravel and through both wood and animal charcoal, in order to remove all sediment from it, and at the same time to remove in part both its color and its odor; but since the methods of refining by distillation have been discovered, it is chiefly the more dense oils that have been treated in this way. These dense natural oils are often injured by distillation in the properties which render them valuable for lubrication, and filtering appears to furnish the only means of removing, even in a partial manner, the color and the often quite disagreeable odor.

Section 2.—MIXTURES OF PETROLEUM.

The mixtures into which petroleum enters are chiefly used for lubrication. They consist of petroleum and heavy products of petroleum mixed mechanically with animal and vegetable oils, tallow, resin, and allied materials, of the same mixed with mineral substances, and also of the same mixed with chemical compounds. The first class of compounds is made in very great variety; in fact, there is scarcely a wholesale oil house in the country but has some formula of its own for compounding lubricating oils, into which petroleum or the products of petroleum enter as a constituent. Some of these are sold honestly as mixtures, while others are adulterations pure and simple. Some of these mixtures are prepared in the rudest manner, and are used only for the coarsest purposes; others are prepared with great care, the mixture being effected by heating and purified by straining or filtering the oil through various materials. The general purpose for which mixtures are prepared is to produce a lubricating material that will be quite as effective as animal or vegetable oils and at the same time be less expensive. A few mixtures are prepared and sold on their merits as preparations of a superior quality, while some dealers maintain that the larger the proportion of mineral oil the better.

The oils used in preparing these mixtures are sperm, whale, and lard oils to a considerable extent, especially for lubrication. Neat's-foot oil and castor oil are used in mixtures for dressing leather. Lard-oil mixtures have been used for oiling wool. In Germany a mixture is sold under the name of "Vulcan oil", which consists of a petroleum distillate of a specific gravity of from 0.870 to 0.890, treated with about 6 per cent. of sulphuric acid and well washed with water, and then mixed with 5 per cent. of rape oil. Another, called "opal" oil, cons sts of petroleum distillate of a specific gravity of from 0.850 to 0.870, similarly treated and washed, and mixed with 10 per cent. of rape oil.

The mixture of petroleum products with mineral substances have only been invented quite recently, and are principally the so-called plumbago oils manufactured in Rochester, New York. By a process which has been patented, reduced petroleum is apparently ground with graphite, as paints are ground in oil, resulting in a complete suspension of the graphite in the oil. It is claimed that these oils are very superior lubricators for railroad axles and steam cylinders, the latter becoming coated with a polished coat of graphite soft as silk. The Johnson Graphite Oil Company publishes a certificate showing that a car had made over 13,000 miles of mileage on one application. It has also been proposed to treat heavy reduced oils with powdered pyrophyllite. This mineral resembles talc, and when powdered is especially soft and greasy to the touch.

The most striking example of chemical preparations of petroleum is perhaps found in the justly celebrated Galena oils, manufactured at Franklin, Pennsylvania. These oils consist of a lead soap dissolved in petroleum. A lead soap is prepared after the ordinary manner by boiling oxide of lead with a saponifiable oil, and the whole is dissolved in the natural heavy oil of the Franklin district. The oils thus prepared have great tenacity and endurance as lubricators, particularly for car-axles, for which purpose they are principally used.

Mixtures of natural oils and tallow, natural oils and residuum, reduced petroleum, residuum from acid-restoring works, containing sulphur, pine tar, etc., are used on car-axles and for other heavy lubrication.

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a A. J. S. (1), xxiv, 63.

CHAPTER II.—PARTIAL DISTILLATION.

SECTION 1.—SUNNED OILS.

The thickening by evaporation of oils spilled upon the Allegheny river and its tributaries, by which an ordinary third-sand oil would become converted into a dense oil fit for lubrication, led to experiments upon the lighter first- and second-sand oils around Franklin that were too light for lubricators and too dense for profitable manufacture into illuminating oils. These experiments were first undertaken by Mr. William H. Brige, of Franklin, and consisted in an attempt to imitate the conditions observed on the river as nearly as possible. Mr. Brige first exposed the oil spread on the surface of water in a small pan 3 feet square. This pan was placed in the sun, and the light oils were allowed to evaporate until the desired consistence was reached. The method was found to be entirely successful. The plan, since adopted on a larger scale, is as follows: A wooden tank is provided, sunk in the ground nearly its entire depth, 60 to 70 feet long, 20 to 30 feet wide, and 1 foot deep. A flat steam coil is laid upon the bottom, and water is run in from 8 to 10 inches deep, upon which a layer of oil about an inch thick is placed. The water is heated by the coil to about 110° F., and the oil becomes very limpid. Every description of dirt, particularly minute particles of grit, that was held in suspension in the viscid oil is left free to fall to the bottom of the tank, and the specific gravity of the oil is reduced in a few days from 32° to 29° B. The oil loses by this treatment about 12 per cent. of its volume, and is increased in value from $5 to $12 per barrel.

SECTION 2.—REDUCED OILS.

Throughout the entire region the observation has been made repeatedly that oil left in open tanks evaporates and decreases in specific gravity Baumé. Mr. George Allen, of Franklin, acting on such observations, patented a novel method of partially evaporating petroleum which produces a very superior quality of oil. He suspends sheets of loosely woven cloth vertically above troughs in a heated chamber and by a perforated pipe distributes the oil upon the upper border of the curtain in thin streams. The oil is thus distributed over a large surface in the heated atmosphere, and the thin film is rapidly evaporated, the light portion passing into the atmosphere, and the heavy portion dripping from the lower border of the curtain into the troughs, from which it passes into a receptacle. This method of treatment furnishes a bright green, odorless oil, entirely free from sediment of any kind, such impurities remaining attached to the curtain. These methods of partial evaporation are particularly valuable, as they preserve all the qualities of the natural oil, without any danger from the effects of overheating.

Many thousands of barrels are reduced every year by partial evaporation in stills, either by direct application of heat or by the use of steam, the evaporation for this purpose being always so carefully conducted as to avoid overheating and "cracking" or any approach to destructive distillation. The different grades of naphtha are usually run off, and then a sufficient amount of distillate is removed to reduce the portion remaining in the still to the required specific gravity. The amount of reduction depends upon the purpose for which the oil is intended, not only with regard to its density, but also with regard to the velocity and temperature at which the machinery is to be run. For use on large journals and those revolving at moderate speed the oil is reduced to a specific gravity of from 29° to 32½° B., but for use on small journals moving with great velocity, and also in the interior of cylinders, where the temperature is very high, a still greater reduction is found necessary, and the oil is made more dense. At the same time it is made less volatile, having a specific gravity of from 26° to 29° B.

A large proportion of the lighter grade oils of West Virginia and Ohio and the entire production of the Smith's Ferry district are treated in this manner. The latter oil is very peculiar, having the color of pale sherry, without its transparency, and when freshly pumped has a specific gravity of 50° B., with a much less pronounced and less disagreeable odor than any other petroleum produced in commercial quantities in the United States. When reduced with the aid of steam the distillate of suitable specific gravity for burning oil requires little or no treatment with acid or alkali, and the reduced oil from the still preserves its amber color and freedom from offensive odor, furnishing a lubricator of very superior quality and attractive appearance.

Reduced oils are often filtered through animal charcoal, and are thereby greatly improved in color and odor.

CHAPTER III.—GENERAL TECHNOLOGY OF PETROLEUM BY DISTILLATION.

SECTION 1.—INTRODUCTION.

Oils were first obtained for commercial purposes by distilling shales and coal early in the present century, but they had been thus produced in small quantities for experiment more than a century before. Gesner, in *Coal, Petroleum, and Other Distilled Oils*, 1861, page 8, says:

As early as 1694 Eele, Hancock, and Portlock made "pitch, tar, and oyle out of a kind of stone", and obtained patents therefor. * * * In 1781 the earl of Dundonald obtained oils from coals by submitting them to dry distillation in coke ovens. * * * Laurent, Reichenbach and others distilled the tars obtained from bituminous schists. These tars were purified in some degree by Selligne, and the oils subsequently obtained an extensive sale in Europe for burning in lamps and for lubricating machinery. * * * Patents were granted in England in 1847 to Charles Mansfield for "an improvement in the manufacture and purification of spirituous substances and oils applicable to the purposes of artificial light", etc. Mr. Mansfield's operations appear to have been chiefly directed to the coal tar of gas works, from which he obtained benzole. He was perhaps the first to introduce the benzole or atmospheric light, which is described at length in his specifications.

From a letter received from the eminent English geologist, E. W. Binney, I extract the following statement concerning the origin of the paraffine oil industry of Scotland:

In 1847 Mr. James Young came to me to ask for information as to petroleum, he having agreed to work some at Riddings, near Alfreton. I gave him all the information I possessed. In 1848 I went over with him to Down Holland Moss (*a*) and showed him the petroleum peat there and brought away samples for him. In the same year I went to Riddings and descended Mr. Oakes' coal-pit and examined the petroleum as it came from the roof of the coal-seam. I then distinctly told him that the oil could be made from highly bituminous coal, distilled at a low heat in a something similar way as the peat and gas-coal yielded it. In 1850 Mr. Young and I became aware of the discovery of a highly bituminous coal at Boghead, in Scotland. We met at the British association, in Edinburgh, at the end of July. I went over to Bathgate, descended the pit where it was wrought, brought a sample of it, and showed it to Messrs. Young and Meldrum, who said they thought it would not make oil. I said that if they could not make oil from it I could. In a day afterward they asked me to join them in a patent to work the invention. Mr. Young was to take out the patent in his name, and Mr. Meldrum and I were to join him in owning and working it. I accordingly bought land, found money, and purchased 10,000 tons of Boghead coal. These works were carried on under the style or firm of E. W. Binney & Co. for fifteen years. I drew the specification of the Young's patent and invented the name paraffine oil, which term was quite new. In 1856 I took out an American patent in Mr. Young's name for the invention, and several parties took licenses in the United States to work it there, paying 2 pence per gallon royalty to us, they fetching Boghead coal from Scotland at a cost of £4 or £5 per ton when delivered. Breckenridge and some other American coals were also used, I believe. As some of these parties refused to pay their royalties, we went to law with them in the states, and their lawyers, having heard that our patent had been the subject of a trial in the court of Queen's Bench, wrote to England for the history of Young's patent, which was reported in the *Journal of Gas Lighting*, in a trial at law, Young *vs.* Hydrocarbon Gas Company, June, 1854. In this trial Mr. Young gave in evidence that he obtained paraffine oil from petroleum before he resorted to coal to obtain it. That would be about 1860; and our American patent never yielded us another cent of royalty. Oil lamps for burning it having been invented in Europe, all was ready for the start of your vast petroleum trade. We always dreaded your native oil coming on us, but we did pretty well before it rushed out, and our patent expired in 1864.

There was no lack of information in this country respecting the properties of petroleum prior to 1860.

Professor Silliman, sr., in 1833, wrote:

I have frequently distilled it in a glass retort, and the naphtha which collects in the receiver is of a light straw color and much lighter and more inflammable than petroleum. On the first distillation a little water rests in the receiver at the bottom of the naphtha, from which it is easily decanted, and a second distillation prepares it perfectly for preserving potassium and sodium, the object which has led me to distill it. (*b*)

In a communication made to the Bradford *Era* of July 4, 1881, some one signing himself "Old Salt Well" gives the following story of the first attempt to refine petroleum in northwestern Pennsylvania. Speaking of the salt-wells near Tarentum, Armstrong county, Pennsylvania, which, with the springs on Oil creek, at that time produced all of the petroleum of that region, he says:

To my certain knowledge they only produced from three to five barrels per day, and I recollect distinctly there was but one well that produced oil only. The wells were pumped, the oil mingling with the salt water. The wells were owned by a gentleman named Kier. When the wells first yielded oil it was placed in four-ounce vials and hawked about the country at 25 cents per bottle as Seneca or rock oil for medicinal purposes. In the year 1854 a small refinery was built at the corner of Grant street and Seventh avenue, Pittsburgh, the point of the old canal outlet into the Monongahela river and the same locality of the present railroad tunnel. It was there the first carbon oil was refined for illuminating purposes. The still did not have a capacity exceeding five barrels. It occupied a one-story building, in size about 12 by 24 feet. In the spring of 1855 I purchased a gallon of the oil, had it placed in a stone jug, and took it home for the purpose of illumination. The kind of lamp in which the oil was used was the same as what was then employed for a substance called burning fluid. The lamp had from one to five small tubes, and was made of britannia or pewter. To trim the lamps cotton-wick was drawn into the tubes, perfectly tight, and the wick was cut down closely until it ceased smoking, and then the lamp was nearly as perfect as any lamp of the period. Each one of those tubes produced a light equal to about two tallow candles. In the year 1876 or 1877 the still that was employed in this immense refinery was displayed at the exposition in Allegheny city, and was labeled as the first still ever used to refine petroleum. In its day it supplied the world's demand for that kind of an illumination. The matter of where the first oil was produced I believe is not the question. Any of the old salt manufacturers about Tarentum can corroborate

a On the coast north of the Mersey.

b A. J. S. (1), xxiii, 101.

what is here stated, and perhaps furnish many interesting details not contained in this brief article. These wells were located 18 miles from Pittsburgh, near the path of the old Pennsylvania canal. Colonel Drake was not the first man to produce petroleum, but he was certainly the first person who drilled a well for the express purpose of finding oil. The questions of when and by whom the first oil was produced and refined can readily be established by indisputable proof.

The Mr. Kier mentioned above was Mr. Samuel M. Kier, before mentioned in this report (see page 10), who, with his friend Mr. McKuen, carried on the enterprise as described. This statement is corroborated by a large amount of evidence from independent sources. It was not a lack of knowledge, but a lack of petroleum, that prevented its use by American manufacturers before 1860. Drake sold his oil to McKuen for 75 cents a gallon.

The editor of the *American Journal of Science and Arts* in 1861 reviewed Gesner's *Coal, Petroleum, and other Distilled Oils*, and says:

The author recognizes the intimate relation of the manufacture of coal oils with the production in such increasing abundance of petroleum, destined to become a powerful competitor of the artificial product for economic use. It is instructive in this connection to recall the fact that the natural product (petroleum), which has been well known from the earliest records of human history, should have remained comparatively useless and almost neglected until the modern art of coal-oil distillation has shown its industrial value. *It is quite possible that the future historian of the industrial arts may look back on the coal-oil distillation as only an episode in the history of the development of the use of petroleum.* (a)

In 1862 Isaiah Warren and his father, being in the lard-oil and candle trade in Wheeling, West Virginia, commenced the distillation of West Virginia petroleum in three 15-barrel stills, and Mr. Warren, sr., was apprehensive that they would glut the market, the price of refined oil then ruling at from 85 cents to $1 15 per gallon.

Section 2.—EARLY METHODS.

The stills in general use at this time were made in three parts, bolted or riveted together, and consisted of a cylindrical cast-iron body, to which was attached a boiler-plate bottom and a cast-iron dome and goose-neck. They held about 25 barrels, were heated from the bottom and bricked up upon the sides, and were sometimes protected from the direct action of the fire by fire-brick. These stills were charged with crude oil, the charge run off, the still cooled, and the coke cut out, often with a cold-chisel. When four-fifths of the oil had been run off the remainder was, when cold, as thick as pitch; at this point some refiners introduced steam, which mechanically expanded and carried over the last volatile portions of the charge, leaving a compact coke, while others distilled to coke without steam. The use of steam at a high pressure in the distillation of Rangoon petroleum and coal had been patented in England in 1857 by Mr. Bancroft, of Liverpool; and Mr. Wilson, a manufacturer of stearic acid, in 1860 used superheated steam in the distillation of natural petroleums. (b) Steam under moderate pressure was also frequently used throughout the entire distillation, both above the charge and injected through it. In the latter case it becomes superheated as the boiling point of the oils rises above that of water; it was, however, considered preferable with the dense paraffine oils to superheat the steam before it entered the oil. Sometimes, after the charge in the retort was partly run off, it was the practice to allow a stream of fresh oil to enter the still about as fast as the vapors were condensed. In this way about twice the ordinary charge could be distilled and the residue of the whole run down to coke. The light naphthas were first taken off and were used for fuel or were allowed to run to waste, there being at that time little or no sale for these products. The distillate was then run to illuminating oil until the specific gravity reached 36° B. = 0.843, and the remaining charge run down till the distillate became of a greenish color. The illuminating oil was then placed in an iron- or lead-lined tank and agitated for one or two hours with oil of vitriol washed, then with water, and afterward treated in the same manner with caustic soda solution of a specific gravity of 1.400 and again washed with water. Some refiners considered this successive treatment with acid and alkali sufficient; others subjected the treated oil to a second distillation, sometimes over solid caustic soda; but this distillation had to be conducted with great care. Some of the earliest and most successful refiners of petroleum on the Atlantic coast were formerly manufacturers of whale and sperm oil, and, having been accustomed to expose their animal oils to sunlight under glass roofs in shallow tanks, they adopted with uniform success the same method of treatment for the mineral oils. Both the color and the odor are improved by this exposure. The heavier naphthas and heavy oils were subjected to redistillation, either alone or with more crude petroleum, and all of the distillate of a proper specific gravity for illuminating oil was carefully separated. The remaining heavy distillate was treated with acid and alkali and sold as "paraffine oil". It was of a dark color and rank odor, and found its way into use very slowly, not only on account of its real inferiority, but on account of violent prejudice against it.

Section 3.—DESTRUCTIVE DISTILLATION.

The general method of manipulation just given was in very general use until about 1865, when the method of cracking or destructive distillation of the heavier oils was generally adopted. A great variety of chemical reagents were used in treating the oils. Solid caustic soda was used in the stills. The oils were washed with nitric acid; bichromate of potash was added to the sulphuric acid, and the combined action of sulphuric and chromic acids

a A. J. S., 1861.

b J. F. I., lxix, 338, 1860; Cosmos, Mar., 1860.

was thus secured; and chloride of lime or bleaching powder in the proportion of 3 ounces to one gallon of oil has been used with hydrochloric acid, the oil finally being treated with lime water. Whatever reagents are used in treatment, it has been found necessary to bring the oil to a uniform temperature above 60° F. In the old form of agitator, when the mixture was effected by machinery, the injection of steam during agitation has been found beneficial both for bringing the oil to the required temperature and to facilitate the washing and settling of the acid and alkaline solutions. (*a*)

In December, 1865, James Young, jr., of Limefield, took out a patent in England for an improvement in treating hydrocarbon oils that was noticed as follows in the *Chemical News* for August 31, 1866:

> This looks like a very valuable invention. The patentee submits the heavier hydrocarbon oils to distillation under pressure, and finds that thereby the heavier oils originally operated upon are converted into oils of lower specific gravity, possessing a higher commercial value. The process may be carried on in ordinary steam boilers (not tubular), which should be proved to 100 pounds; but it is not found necessary to operate much beyond a pressure of 20 pounds to the inch. The means of regulating the escape of the vapor, and of condensing it, can be easily imagined. The operation may be carried on with the crude products of the original distillation, or the lighter oils may first be separated by an ordinary rectification, and only the heavy oils submitted to this treatment. (*b*)

At about the time that this invention was patented in England the same results were obtained in the United States by an entirely different method of manipulation. This method consisted in a slow and repeated distillation, which produced destructive distillation of the medium and heavy oils, converting them into oils of a density suitable for illumination with a production of gaseous products and deposition of carbon. In order to accomplish this result the brick casing was removed from the stills, and after that portion of the distillate suitable for illumination had been separated the fires were slackened and the vapors of the heavy oils as they rose into the dome of the still were allowed to condense and drip back upon the hot oil below, which had meanwhile been heated to a temperature above the boiling point of the oil dripping upon it. This practically superheats the vapors of the oils and produces decomposition. The effect of distillation under pressure is precisely the same: the oils are distilled at a temperature above their normal boiling points. By this method of distillation the petroleum can be converted into naphtha, illuminating oil, and coke, with a certain amount of gas either escaping into the atmosphere or being burned as it escapes. The illuminating oil may be collected in one receptacle and be made of uniform grade, or that portion of the petroleum suitable for purposes of illumination can be separated from that produced by destructive distillation, thus furnishing two grades of illuminating oil which are quite different in composition and quality, the light oils in the crude petroleum being superior to those produced by the decomposition of the heavier portions of the oil. This method of distillation had been successfully pursued in treating the distillates from coal before the introduction of petroleum, but it was not generally applied to the treatment of petroleum, especially in very large stills, until about the time here indicated. Its successful introduction and general adoption was, however, the result of an accumulated experience, not only in the distillation, but quite as much in the subsequent treatment of the oil with acids and alkalies, especial regard being had to the temperature while undergoing treatment. The result of the adoption of this method of manipulating the oil by one distillation was the gradual separation of petroleum refiners, in a general way, into two classes: a small number who continued to manufacture a variety of products from petroleum, and a large number who manufactured principally illuminating oils. While the division thus made is correct in a general sense, it must not be understood as applying strictly to all the parties engaged in manufacturing petroleum. There are those who reduce petroleum and sell their light distillates; others who reduce petroleum and treat their own distillates; others who produce nothing but enormous quantities of crude naphthas, illuminating oils, and residuum, selling their crude naphtha to parties who redistill and fractionate the naphtha into several products—their illuminating oils to the general trade, and their residuum to manufacturers of lubricating oils; others who refine and fractionate crude naphtha; others who manufacture lubricating oils, using both crude petroleum and residuum for the purpose; others who manufacture in one establishment nearly everything that can be made from petroleum; and still others who have special processes by which peculiar products are obtained. It is unnecessary to describe in detail all of these different methods of conducting the business of manufacturing petroleum; it is sufficient for my purpose to describe carefully what may be termed two typical establishments, and then to describe a number of processes that are used for special purposes.

SECTION 4.—DESCRIPTION OF THE APPARATUS USED IN MANUFACTURING PETROLEUM.

Before describing the process above mentioned, it will be necessary to describe in detail the apparatus which is in general use in such establishments.

LOCATION.—The largest petroleum refineries in the country are at tide-water at Hunter's Point and Newtown creek, Long Island; Bayonne, New Jersey; Point Breeze, below Philadelphia, and at Thurlow, below Chester, on the Delaware; and near Baltimore, Maryland. At Bayonne, New Jersey, the Standard and Ocean refineries have piers 1,000 feet in length, with sufficient water to float the largest ships and facilities for loading from 6,000 to 7,000 barrels of refined oil daily. In western Pennsylvania and Ohio the refineries are usually located upon the side of a hill, the storage-tanks for crude oil being placed highest and the oil distributed by gravity so far as is possible.

a See *Chemical News*, vi, 230.

b C. N., xiv, 108.

BUILDINGS.—The buildings of refineries are in the greatest variety possible. In the older establishments, particularly in the Atlantic cities, the works are carefully inclosed with substantial buildings of brick and iron, while the other extreme is to be observed in newer establishments, either just going into operation or being rebuilt after destructive fires, when scarcely anything about the place except boilers, engine, and pumps is covered, the receiving-tanks being underground and the stills without any covering at all. The works of the Downer Kerosene Oil Company, at South Boston, have always been very carefully inclosed in valuable brick buildings, and no serious loss has occurred there for many years. Some of the immense refineries at and around Hunter's Point, Long Island, are also fully inclosed; but the works of the Tide-Water Pipe Company at Thurlow, Pennsylvania, on the Delaware, only recently constructed, and said to be one of the most complete establishments of the kind, are almost as completely exposed to the elements as those of the smallest and rudest concerns in the oil regions. The boilers are placed in one building, the pumps in another, the office in another, all of which are of brick; but the stills and condensers are without any covering whatever. The distillate tanks are all underground; the agitating tank is isolated and uncovered; and the sunning and spraying tanks are in buildings made of rough boards, and are of little value. The works of the Acme Oil Company, at Titusville, Pennsylvania, built to replace those burned during the census year, appear to be built on a hillside from which fire has removed even the soil, and to be without a building or a covering of any description.

TANKAGE.—The oil is received at the refineries either from pipe-lines or from the tank-cars of transportation companies, and in either case it is pumped into vast storage-tanks holding from 10,000 to 36,000 barrels each. The tank-cars are provided with gates or valves on the under side, to which hose may be attached, and connections are made with a large pipe laid beneath the track, into which the oil rushes as soon as the gates are opened. This pipe discharges the oil into a tank, from which it is pumped to the storage-tanks. In these tanks from one to two per cent. of water settles, and from them the oil is pumped into the stills.

STILLS.—A great variety of stills are in use for different purposes, and the greater the variety of products produced from the petroleum the greater will be the variety of stills in use as regards both size and form. In some establishments the old cast-iron, upright cylindrical still, with wrought-iron bottom, is still in use. To these have been added plain, horizontal wrought-iron cylinders of various sizes. One of these, as now quite generally used, is represented with the setting in the vertical section in Fig. 37, and a bank of three, as they are usually set, in Fig. 38. From these sections it will be observed that they are 12 feet 6 inches in diameter and 30 feet in length. The vapors rise into a dome 3 feet in diameter, from which they pass to the condenser through a single pipe 15 inches in diameter. No more simple form of still could be devised. The so-called cheese-box still, now in great repute, is shown with the setting in horizontal and vertical section in Figs. 39 and 40. It is 30 feet in diameter and 9 feet high, with a dome-shaped top, and works 1,200 barrels of crude oil. The bottom has a double curve, to allow of expansion; the sides are of five-sixteenths-inch wrought-iron and the bottom of five-sixteenths-inch steel, the whole inclosed in a sheet-iron jacket. The center is supported upon a cylindrical pier of brickwork, through which the products of combustion are led to the stack. The circumference is supported upon seventeen arches, in sixteen of which are fireplaces, the sides of which converge toward the center and discharge over a bridge-wall through four arches into the center of the pier just mentioned. Through the seventeenth arch passes the discharge-pipe from the bottom of the still. The vapors escape from this still through three pipes, two of which may be closed by cocks, into a sort of chest or drum (Fig. 41), from which 40 pipes 3 inches in diameter pass through to the condensing tanks. Steam is introduced into the heated vapors as they escape from both the cylindrical and cheese-box stills by placing a curved and perforated pipe of the form shown in Fig. 42 at the point where the vapors emerge from the still and enter the exit pipe. The use of steam in this manner is found to improve both the color and the odor, especially of "cracked oils".

Several attempts have been made to produce continuous distillation; but I cannot learn that any of them have proved commercially successful, although an apparatus of the kind erected in Buffalo has been put in operation and distillates have been produced that were treated and sold. This apparatus was patented by Samuel Van Syckle, of Titusville, Pennsylvania, May 22, 1877, No. 191203. It consists of a series of stills, in which the oil is maintained at a constant level by means of a tank, in which a float on the surface of the oil as it rises and falls automatically controls the flow. The first still is maintained at such a temperature that the naphthas and other light products are removed, and in the other two the illuminating oils are removed so effectually that residuum may be drawn off from the last still. I think this apparatus should be more thoroughly tested before its merits are finally judged, especially as to how far its value is modified by complexity and expense of manipulation.

Another apparatus, evidently much more simple in construction than Van Syckle's, but at the same time not calculated for handling the enormous quantities of oil refined in this country, has been patented in Germany by Herr Fuhst. (*a*)

The deodorized lubricating oils, of which Mr. Joshua Merrill, of the Downer Kerosene Oil Company, was the inventor, have been prepared by him in a still of peculiar construction, especially adapted to the treatment of petroleum and kindred substances. An accident suggested the preparation of these oils to Mr. Merrill. In

a Dingler, ccvii, 293.

November, 1867, the condenser to a still, in which a quantity of oil too heavy for illumination and too light for lubrication was being fractionated, became obstructed from some accidental cause, and the pressure became so great that the leakage caused the fires to be drawn and the whole thing to cool down. The still was started with 900 gallons, from which 250 gallons was found to be removed by the partial distillation. On removing the remaining oil, Mr. Merrill was surprised to find it different from any petroleum product he had ever seen before. "It had a bright yellow color, was clear, very nearly odorless, neutral, and dense. Further experiment showed this result to have been obtained by the removal of all the light odorous hydrocarbons without decomposing either the distillate or the oils remaining in the still; and that this had been accomplished by the moderate fire employed, and its gradual withdrawal." (*a*)

This mode of operating was immediately applied to other distillations, and in order to accomplish the result most effectually Mr. Merrill invented a method of superheating steam within the body of the oil itself. Within a still of moderate size, holding perhaps 1,000 gallons, he placed a steam coil, which terminated upon the exterior of the dome of the still. After attaching a valve, the steam-pipe is returned into the still and a perforated coil of pipe connected with it, which lies flat upon the bottom. The still is heated by direct heat, and as the temperature rises the steam, as it passes through the first coil, is heated and is distributed through the entire mass of oil as it escapes from the perforations in the second coil. The steam is regarded by Mr. Merrill as an important adjunct in this method of fractional distillation, as it acts mechanically by carrying forward the vapors into the condenser, and also prevents the overheating and "cracking" of either the oils or the vapors.

When the destructive distillation of petroleum commenced on a large scale, the slow distillation necessary to effect this decomposition led to an increase in the size of the stills until the enormous capacity of 2,000 barrels, or 80,000 gallons, was reached. These immense stills were built without covering, were freely exposed upon their sides and tops to the elements, and were heated by numerous fires, placed at equal distances from each other upon the circumference of the still, after the manner of the setting of the cheese-box still. These excessively large stills are not now being used. Refineries lately put in operation are equipped with stills holding about 1,200 barrels each.

Vacuum stills have been used to some extent, and have been employed especially in the United States by the Vacuum Oil Company, of Rochester, New York, in the preparation of the peculiar products of their manufacture. Of course the evaporation in these stills takes place rapidly and at the lowest temperature possible, insuring a fractional distillation, not a decomposition, of the oils.

CONDENSERS.—Large copper worms, similar to those used in distilleries, were at first used for petroleum stills. These were soon replaced by ordinary iron piping coiled in a cistern or tank of water, and still later very long, straight pipes were used with advantage in the use of water for cooling. Refineries lately built are provided with condensers of moderate length, 50 by 20 by 8 feet, in which there are numerous separate pipes, which receive the vapors at one end and discharge the condensed oil at the other. A condenser thus constructed may consist of forty separate 3-inch pipes, each 45 feet in length, giving an aggregate length of 1,800 feet, the oil and vapors, instead of all traversing the entire length of 1,800 feet, being divided into small portions, each of which is made to traverse the 45 feet, and is condensed. The ratio of exposed surface to cubical content is very much increased by this arrangement over a shorter pipe of larger diameter.

A very convenient arrangement for dividing distillates is shown in the section in Fig. 43. In this section *a* is the 2-inch pipe leading from the condenser, *b* is a pipe for uncondensed gases leading to the boiler furnace, *c* is the trap for holding back the gas, *d* is a wrought-iron box with a glass front *i i*, through which the flow of oil from the condenser can be observed. The glass front is on hinges, and can be opened for sampling the oils. From this box the oil passes into the pipes below, and is directed into one of the openings *g*, through which it enters the pipe *h h*, leading to the storage-tanks for distillate; *e e* are three-way cocks, and *f f* ordinary stop-cocks, by which the oil is directed to one of the six orifices *g*. By this arrangement, by simply opening or closing the cocks, the distillate can be directed to any one of six receptacles and be divided into as many different portions.

AGITATORS.—The agitators used at first were small tanks lined with lead, in which various mechanical contrivances were used to effect the thorough mixing of the oil with the chemicals. These lead-lined tanks were replaced by wrought-iron ones, and finally the method of agitating by mechanical means has been entirely superseded by agitation by means of injected air. The agitators in use in refineries lately constructed are high wrought-iron tanks of comparatively small diameter, holding several hundred barrels of oil, in which the most complete agitation is produced by a current of air injected by a blowing apparatus.

PUMPS.—The pumps used in refineries are many of them very powerful. Those used for pumping oil and water are of the Worthington or the Drake pattern, and consist of an engine and a pump combined. Some of these pumps are large enough to handle 2,500 barrels of crude oil an hour, but the majority are smaller. In addition, there are in use small blast-engines or air-pumps to force air into the agitators and into the acid-tanks. The latter are small lead-lined tanks, into which the acid is emptied from carboys or tank-cars. The acid is measured into the agitators by forcing it from the tank into the agitator under pressure of injected air.

PACKING.—Manufactured oils of all kinds are distributed to wholesale houses all over the country in tank-cars, but for the jobbing and retail trade they are packed in barrels and in tin cans. The barrels used at present hold from

a S. D. Hayes, Am. Chem., ii, 401; C. Cbl., 1871, 783; W. B., 1871.

48 to 50 gallons, and manufactured oils are estimated at 50 gallons to the barrel. The tin cans contain 5 gallons each, and are packed in wooden cases, each of which holds two cans. In the larger establishments the packages are filled by weight, as the bulk of the oil varies with the temperature and specific gravity of the oil, as may be seen at a glance at the table accompanying this report (see page 112). The filling of the 5-gallon cans is carried on at a square, revolving table. Ten cans are closely ranged along one side of this table and brought beneath ten funnels, which deliver oil to the cans until their weight stops off the oil by tipping a balance and closing a stop-cock. The ten cans are then swung out by giving the table a quarter revolution. While these cans were being filled another ten cans were placed upon the adjoining side of the table, and when the first were swung from under the funnels the second were brought into their places. While the second ten cans are being filled a third set are being placed upon a third side of the table, and a nozzle, with a cap that screws on and off, is placed in position for soldering over the orifice through which the first ten cans were filled. The table is again swung, the third set of cans are brought into position, and are then filled; the second set are supplied with nozzles, while the nozzles of the first set are soldered on and the fourth side is supplied with ten cans. Another swing of the table, and the fourth set are filled, the third supplied with nozzles, the second soldered, and the first removed, and a fifth set is put in their places. Several thousand cans can be filled in this manner at one of these tables in a single day.

SECTION 5.—DESCRIPTION OF AN ESTABLISHMENT IN WHICH THE PRODUCTS ARE GENERAL.

The plant consists of storage-tanks for crude material; stills, heated by fire, steam, and superheated steam; agitators; chilling-house for paraffine; boilers, engines, pumps; a laboratory; cooper and tin shop. The crude oil is delivered in pipes or tank-cars to the general storage-tanks and allowed to settle. From one to two per cent. of water separates. (*a*) About 300 barrels (12,000 to 13,000 gallons) of this oil are placed in a still and "live steam", *i. e.*, at 212° F., is admitted, and the distillation carried on until the distillate marks 60° B. With crude petroleum of 45° B. the amount of this distillate will be from 12 to 15 per cent., divided as follows:

A.

	Per cent.
1. "Crude gasoline", to 80°, about	½
2. "C" naphtha, 80° to 68°, about	10
3. "B" naphtha, 68° to 64°, about	2 to 2½
4. "A" naphtha, 64° to 60°, about	2 to 2½

1 is redistilled by dry heat, and yields from 90° to 83° gasoline, which is not treated; 83° to 80° is returned to crude gasoline.

2 is treated with 4 ounces of oil of vitriol to the gallon and washed with caustic soda, all cold, and then redistilled by steam from an alkali solution. Its average specific gravity is 70°, and it is known in the trade as benzine-naphtha.

3 and 4 are also treated with acid and caustic soda. The average specific gravity of 3 is 65° to 66°, and of 4 62°.

There remains in the still from 88 to 85 per cent. below 60°. This is transferred to cylindrical cast-iron stills with meniscus-shaped wrought-iron bottoms and distilled by direct heat, with 2 per cent. of soda solution of 14°. The distillate is thus divided:

B.

	Per cent.
1. Crude burning oil, from 58° to 40°, about	50
2. "B" oil, from 40° to 36°, about	20
3. From 36° downward, about	25
4. Cokings or residuum	3
5. Loss	2
	100

1 is treated with 4 ounces of oil of vitriol to the gallon and is agitated for half an hour. It is then drawn off from the tarry residue, and after being washed with water is again agitated for an hour with 2 per cent. of alkali solution, and is then drawn off and next day washed with a large amount of water, pumped into a fire-still upon a solution of soda equal to 4 per cent. of 14°, and distilled as long as the color is good, the amount usually being about 80 per cent. This distillate is the equivalent of "Downer's standard kerosene", and has a specific gravity of 45° and a fire-test of 125° F. The remaining 20 per cent. is run above 36° to crude burning oil (B 1), and below 36° to "finished machinery oil" C, to chill and press for paraffine.

2. "B" oil is distilled like 1 on soda lye. Of the distillate, above 36° goes to crude I; below 36° to the machinery oil C, to chill and press for paraffine.

a As high as 13 per cent. of water has been obtained from residuum exported to England. It is not a legitimate mixture. C. N., xxx, 57.

3 goes to crude lubricating oil, and is treated with 4 ounces of acid to the gallon upon water at 212° F. for one hour, and is then distilled from a 2 per cent. solution of soda lye. Of this distillate above 40° goes to crude B 1, from 40° to 36° to B 2, from 36° downward, as long as the color is good, to machinery oil C, to chill and press for paraffine.

4 goes to coking-tanks.

C.—MACHINERY OIL, 36° AND DOWNWARD.

This oil is twice distilled and chilled in barrels packed in an ice-house for a week with ice and salt at 26° F. The crystalline *magma* is pressed in an hydraulic press and yields:

1. Crude scale paraffine (E).
2. Pressed lubricating oil of a specific gravity of 32°, which is partly sold as "spindle oil".
3. The portion not sold as spindle oil is placed in a still provided with coils for distilling with steam superheated within the oil itself. This still is heated with direct heat until the temperature has reached 250° or 300° F. Steam is then passed into a coil, which is immersed in the body of the oil, and is then allowed to escape into the oil through another coil, which is perforated, thus distributing the steam throughout the oil at the same temperature as the oil itself. Twenty to 30 per cent. of the lighter products, with all those having an offensive odor, ranging in specific gravity from 50° to 32°, are lifted from the still by the steam. Of this distillate, that between 50° and 40° goes to B 1, that between 40° and 32° to "crude mineral sperm" (D), and the oil left in the still is equivalent to "Merrill's deodorized neutral hydrocarbon oil", with a specific gravity of 29°. To remove fluorescence chromic acid is used instead of oil of vitriol.

D.—MINERAL SPERM ILLUMINATING OIL.

This is the trade-mark of a dense oil of 36° specific gravity, deprived of offensive odor, and adapted especially for light-house and locomotive lights. Any crude distillate from 40° to 32° is first treated with 4 ounces of oil of vitriol to the gallon, then washed with a solution of caustic soda, and distilled by direct heat over soda lye. It has a fire-test of 300° F. and but little odor, with a density of 40° to 34°, averaging 36°. Below 34° goes to machinery oil (C), to chill and press for paraffine.

E.—CRUDE-SCALE PARAFFINE.

The pressed scale equals three-quarters of a pound per gallon of the crude 32° machinery oil from the chilled mass described in C. To refine this the crude scale is melted in an open tank by live steam, blown in, with 1 per cent. of caustic soda lye, from which it is carefully drawn and then well mixed with 25 per cent. of "C" naphtha and put aside for three or four days in shallow metallic pans in a cold place. It is then again cut, bagged, and pressed.

No. 1 paraffine stock is remelted in "C" naphtha on alkaline lye, crystallized and pressed three successive times, and yields large crystals of paraffine, melting at 130° F.

No. 2 paraffine stock is treated in the same way, furnishing a product of less value in smaller crystals, melting at about 116° F., and is largely used by chewing-gum manufacturers. The oils expressed go to crude "C" naphtha

F.—COKINGS, SPECIFIC GRAVITY 28°.

These are redistilled over a 2 per cent. alkali solution, and furnish—

20 per cent. above 40° goes to B 1.

15 per cent. 40° to 36°, goes to B 2.

50 per cent. 36° and downward, as long as the color is good, goes to C.

10 per cent. cokings.

5 per cent. loss.

G.—SLUDGE (RESIDUES FROM WASHINGS).

The waste "acid sludge", 48° to 50°, is permitted to stand two days, and the oil rising upon it is drawn off ("sludge acid oil") and the acid disposed of. The sludge oil is then washed with the waste alkali and redistilled separately without fractions, yielding 80 per cent. of oil; coke and loss, 20 per cent. The coke is used as fuel, and the oil redistilled on alkali and fractioned as crude oil below 60°.

H.—AVERAGE PERCENTAGE OF COMMERCIAL PRODUCTS OBTAINED FROM CRUDE PETROLEUM OF 45° FROM NEW YORK, PENNSYLVANIA, OHIO, OR WEST VIRGINIA.

	Per cent.
Gasoline	1.0 to 1.5
"C" naphtha	10.0 to 10.0
"B" naphtha	2.5 to 2.5
"A" naphtha	2.0 to 2.5
	16.5
Illuminating oil	50.0 to 54.0
Lubricating oil	17.5
Paraffine wax = $4\frac{1}{2}$ pounds per barrel	2.0
Loss	10.0
	100.0

The oils prepared by this process are all of the highest degree of excellence, and have commanded the confidence of consumers both in the United States and in all other civilized countries to a remarkable degree. There are two essential particulars in this process as a whole to which I desire to call attention. All destructive distillation is avoided so far as is possible, and great care is taken to render the different products pure as regards each other, and also as regards the effects of treatment. The products are essentially paraffine products, using that word in a generic sense to designate not only the paraffine wax, but the whole series of compounds to which it is related, from marsh-gas upward. The finishing of the burning oil by distillation over caustic soda is claimed, and I believe justly, to remove all of the substitution compounds of sulphuric acid that are only completely removed even by solution of caustic alkali when the oil is heated to a temperature above the boiling point of water. (*a*)

SECTION 6.—DESCRIPTION OF A MANUFACTORY WHERE NAPHTHAS, ILLUMINATING OILS, AND RESIDUUM ARE PRODUCED.

The following description is given after an inspection of one of the most complete establishments in the country, lately constructed and furnished throughout with an equipment of the most improved apparatus:

The oil is received in tank-cars, and an entire train is discharged at once into a 12-inch pipe, which runs the length of the siding between the rails and beneath the sleepers, connection being made with cocks underneath the car-tanks by union joints and hose. This 12-inch pipe discharges into a tank, from which the oil is pumped by a Drake steam-pump, handling 2,500 barrels an hour, which throws the oil either to the stills or to the storage-tanks, of which latter there are four, holding 35,000 barrels each. The capacity of this pump is not required for the storing of oil, but for the filling of the stills, of which there are nine, holding 1,200 barrels each. Three of these stills are cheese-box stills, and six are plain cylinder stills, 30 feet by 12 feet 6 inches, the former being set in one group, and the latter on a bench, side by side, like a bench of boilers. These stills are all covered with sheet-iron jackets, but are not otherwise protected or covered in any manner. The condensers are made in the manner described on page 163, with a large number of separate strands of pipe, which are immersed in a tank 50 by 20 by 8 feet. These strands enter a connecting pipe which emerges from the tank and enters a small building, where the discharge pipes from the nine stills are brought together side by side. Each discharge pipe terminates in a U-shaped gas-trap, and enters an iron box with a glass front, through which the flow of the oil from the pipe may be observed. The arrangement of the traps and the form of the boxes are shown in section in Fig. 43. The gas-pipes from the nine traps all connect with furnaces beneath the steam-boilers, where the gas, mixed with air, is burned after the manner of a Bunsen burner. The division of the distillates is effected by means of an arrangement of pipes and cocks shown in section in Fig. 43. Each of the nine boxes *d* (Fig. 43) discharge through this set of pipes, by which the distillate may be divided into six different qualities. These six different pipes connect under ground with the distillate tanks, which they enter at the bottom, and are sealed by the contents of the tanks. These nine sets of boxes and pipes are placed in a small building, lighted at night by an electric light, placed upon a pole at some distance off on the outside. The petroleum is put into the stills, and the crude naphtha is run off. Then that portion of the petroleum is run off which is necessary to prepare the distillate for "high-test" oils having a fire test of from 120° to 150°, as may be required, and these latter oils having been run off, the residue in the still is in a condition for "cracking". The fires are then slacked, and the distillation is run more slowly, a large amount of permanent gases being disengaged and burned under the boilers. Until the process of cracking is commenced the amount of gas disengaged is inconsiderable, so small in amount as to be scarcely worth the trouble of burning; but after cracking commences the gas generated is nearly sufficient to supply the fuel necessary for the boilers. The distillates are pumped into the agitating tank, which stands by itself, supported on a massive base of timber. It is about 40 feet in height and 12 feet in diameter. Twelve hundred barrels of distillate and 6,600 pounds of oil of vitriol are placed in this tank. The carboys of oil of vitriol are emptied into an air-tight, lead-lined tank, which is closed, and air is forced into it until a sufficient quantity of acid has been driven by the pressure into the agitator. The agitation is then carried on by forcing air into the agitator under a pressure of from 5 to 7 pounds. The acid being drawn off, the oil is thoroughly washed with water, then with a solution of caustic soda, and lastly with water containing caustic ammonia, the treatment with ammonia being supposed to complete the removal of the compounds of sulphuric acid. The oil is discharged from the agitator into settling and bleaching tanks, 40 by 5 feet, having a capacity of about 1,200 barrels each, through a perforated pipe standing perpendicularly in the center. By this process, which is called "spraying", the oils, particularly those that have been cracked, are brought up to "test" by the evaporation of the small percentage of very volatile oils that are combustible at a low temperature. These huge tanks are exposed beneath sky-lights, where the color of the oil is improved by the sunning, every particle of water or sediment settling at the bottom. From them the oil is pumped to storage-tanks in the barreling and canning house, where it is barreled in glued barrels or filled into 5-gallon cans, two of which are packed in a wooden case for shipment. From the packing-house the barrels and cases are put on board ships that lie at the adjoining

a I have drawn largely for this description upon Dr. J. Lawrence Smith in his report on petroleum to the Philadelphia Centennial Exhibition. Rep. Judges of Group III.

piers. This is the simplest process for manufacturing petroleum, consisting only of a single distillation; and the methods employed in the different manufactories throughout the country are either substantially that just described, or a combination with more or less of the processes described in the preceding section, or one or more of the special methods to be described in the section which follows.

Section 7.—MISCELLANEOUS PROCESSES.

Refining crude naphtha.—There are several firms whose business consists mainly in refining crude naphtha, the larger portion of it being divided into gasoline and C, B, and A naphthas. In 1866 Dr. Henry J. Bigelow, of Boston, requested Mr. Joshua Merrill, of the Downer Kerosene Oil Company, to prepare the most volatile fluid possible to be obtained from petroleum. Mr. Merrill redistilled gasoline by steam heat, and condensed the portions that came over first with a mixture of ice and salt, obtaining 10 per cent. of the gasoline, equal to one-tenth of 1 per cent. of the original petroleum, in the lightest of all known fluids, having a specific gravity of 0.625 and a boiling point of 65° F. This fluid was named rhigolene by Dr. Bigelow. Its evaporation at ordinary temperatures is so rapid that a temperature of 19° F. below zero has been obtained by its use. Five or six hundred gallons have been prepared by the Downer company for use in surgical operations, but none was prepared by them during the census year.

A similar material, called cymogen, has been prepared in a similar manner by other manufacturers, and has been used as the volatile fluid in ice-machines.

The distillate separated as gasoline ranges in specific gravity from 90° to 80° B., and is used for the gas-machines that carburet air.

"C" naphtha includes the distillate between 80° and 68° B., and is used for varnishes, sponge lamps, paint, and naphtha street lamps. It is sold under the name of "benzine".

"B" naphtha includes the distillate between 68° and 64° B., and is also used for varnishes and paints.

"A" naphtha includes the distillate between 64° and 60°, and is used in the manufacture of floor-cloths and patent leather. Below 60° goes to illuminating oil.

Each of the different grades of naphtha is deprived wholly or in part of its disagreeable odor by being filtered through beds of gravel and wood or animal charcoal.

"Mineral sperm."—This is an illuminating oil prepared originally by Mr. Joshua Merrill, of the Downer Kerosene Oil Company, and now chiefly manufactured by that company, and is obtained by partially cracking paraffine oils and fractionating the lighter from the heavier products in Merrill's double-coil still or some similar contrivance. It has a fire test of 300° F. and upward, is an illuminating agent of great power, and is as safe from ordinary combustion as sperm oil. This oil is used in manufacturing establishments and on ocean steamers, and is a very suitable material with which to light steamers and cars designed for the conveyance of passengers. The amount produced during the census year was 16,544 barrels.

Neutral lubricating oils.—These oils were also discovered by Mr. Merrill, as before described, and their superior quality soon led to their imitation and manufacture by other parties, although that gentleman protected his discoveries and invention by patent. Since the Downer company commenced the manufacture of these oils the general character of all of the mineral lubricating oils in the market has been greatly improved. The paraffine oils manufactured prior to this discovery were dark in color and rank in odor, but Mr. Merrill produced oils odorless and tasteless. Five per cent. of sperm oil mixed with 95 per cent. of Merrill's neutral oil could not be detected by either the odor or taste from pure sperm oil. An inspection of the tables representing the articles manufactured from petroleum during the census year will show that 79,465 barrels of paraffine oil are reported, all of which was greatly superior to the paraffine oil of 1865; of deodorized lubricating oils there were manufactured 70,415 barrels. These really superb oils are now being introduced into many manufactories by order of the insurance companies. The value of having a deodorized lubricating oil can be fully realized when it is stated that experiments have shown that when a heavy hydrocarbon containing so little as 1 or 2 per cent. of light offensive oil is employed in a warm apartment as a lubricator of machinery the entire atmosphere of the apartment will be impregnated by the pungent and disagreeable odors of these volatile products. Before the employment of these odorless oils this was a great inconvenience in factories. (*a*)

Mr. Merrill prepares lubricating oils by subjecting an ordinary paraffine distillate, from which the paraffine has been removed by chilling and pressing, to fractional distillation in his double-coiled still, but oils may be prepared that are similar, though not fully equal, to his in an ordinary still, provided care is taken not to crack them.

Filtered oils.—A very superior quality of lubricating oil is prepared by reducing petroleum and filtering the reduced residue through beds of animal charcoal. The oil is reduced to the proper degree of volatility and specific gravity and then filtered. These oils sustain a very high reputation, but precisely what relation they bear in quality to the neutral oils obtained by distillation and treatment I cannot state.

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a Loc. cit. Rep. of Judges of Group III, p. 153.

VACUUM OILS AND RESIDUES.—Vacuum oils are also prepared in stills for a great variety of purposes. Those most dense and with highest boiling points are prepared for oiling the interior of steam cylinders; those less dense for journals; and a less dense oil is used extensively for oiling harness and harness leather. Very dense residues prepared in vacuum stills are filtered while hot and very fluid through beds of animal charcoal, the resulting product being an amber-colored material of the consistence of butter and nearly destitute of odor. These residues are largely used as unguents under the name of cosmoline, vaseline, petrolina, etc. The details of their manufacture are difficult to obtain, for the reason that the manufacturers are engaged in suits involving patent rights to peculiar processes of manufacture and peculiar apparatus for effecting the filtration, which necessarily must be carried on at a sufficiently high temperature to insure complete fluidity of the material. These preparations will be further noticed under the chapter devoted to petroleum in medicine.

It is believed that but few, if any, general methods of any importance pursued in the manufacture of petroleum have been omitted in this chapter. It is a subject, however, embracing multitudinous details and carried on under conditions of great diversity, incident to the location of the business and the peculiar character of the crude oil used or the products which the manufacturer wishes to prepare.

CHAPTER IV.—PARAFFINE.

SECTION 1.—HISTORY.

Wagner's *Berichte* for 1869, in an historical notice upon paraffine, says:

The *Aerztliche Intelligenzblatt*, of Munich, contains the following notice: "The opinion universally held that the chemist Karl Freiherr von Reichenbach, who died in his eighty-first year, of old age, at Leipzig, January 19, 1869, was the first to investigate the paraffines, deserves the following corrections or amendments. In 1809 these bodies were observed by John Nep. Fuchs in Landshut in the petroleum of Tegernsee, and in 1819 Andrew Buchner, sr., produced them in a pure state from the oils. Buchner describes their peculiarities under the name of 'mountain' fats, whose identity with paraffine was established later (1835) by v. Kobell beyond doubt. Unqualified merit, however, belongs to Reichenbach as having first discovered paraffine in the products of the dry distillation of wood and other organic bodies." Reichenbach remains the discoverer of paraffine notwithstanding the fact that, beside Fuchs and Buchner, Saussure and Mitscherlich investigated a fatty body found in certain petroleums and tars which after the discovery of paraffine proved to be identical with this body. In all of these conditions the discourse was upon paraffine as an *educt*, and not as a *product*. Technology distinguishes the former from the latter through the name of *Belmontin*. He who first considered fossil paraffine can upon no condition lay claim to the honor of the discovery. In Moldau and in Galicia fossil paraffine has been used for centuries in making candles, as also on the Caspian sea and in the Caucasus. (*a*)

It appears from this statement, which is in accord with numerous authorities, that fossil paraffine has been known in Europe from time immemorial, and also that paraffine, as a recognized constituent of certain bodies of organic origin, was discovered by Reichenbach in 1830, (*b*) and named by him from *parum* and *affinitas*, indicating that paraffine is destitute of chemical affinity; in other words, that it is neutral, having neither acid nor alkaline properties. In the following year Christison, of Edinburgh, made known his discovery of paraffine in the petroleum of Rangoon. (*c*) He at first called it *petroline*, but after learning of Reichenbach's discovery he admitted its identity with paraffine. In 1834, Gregory published an article on paraffine and eupion and their occurrence in petroleum, in which he says:

It follows that there are some kinds of naphtha (petroleum) which contain paraffine and eupion, and are consequently the results of destructive distillation. (*d*)

In 1835, Kobell independently mentions paraffine as a constituent of petroleum. (*e*) In 1833, Laurent showed that oil distilled from shale in the environs of Autun contained paraffine. (*f*)

Although Reichenbach distilled coal in considerable quantities, and had at his disposal the resources of the immense establishment of "mines, iron furnaces, machine-shops and chemical works, etc.," on the estate of Count Salm at Blansko, Moravia, of which he was superintendent, he cannot be said to have produced paraffine on a commercially successful basis. This work was performed by Selligue, whose inventions formed the foundation upon which the technology of coal-oil and petroleum has been built. The following digest of the labors of Selligue is taken from the review of Dr. Antisell's work on photogenic or hydrocarbon oils by Professor F. H. Storer: (*g*)

In 1834 we find for the first time an article describing the process of Selligue, (*h*) although it would appear from the statements of this chemist and of others that his attention had been directed to the subject of distilling bituminous shales several years earlier.

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a W. B., xv, 709, 1869.
b *Jour. für Chem. u. Phys.* von Schweigger-Seidel, 1830, lix, 436.
c Trans. Roy. Soc. of Edinburgh, xiii, 118; *Repertory of Patent Inventions*, 1835 (N. S.), iii, 390.
d *Ibid.*, xiii, 124; *Ibid.* (N. S.), iv, 109.
e *Jour. f. Prak. Chem.*, v, 213.
f *Ann. de Chim. et de Phys.*, liv, 392.
g Am. J. S., xxx, 1860.
h *Journal des Connaissances Usuelles*, Dec., 1834, p. 285; Dingler, lvi, 40.

* * * In 1834, '35, and '36 Selligue was principally occupied with his process for making water-gas. (*a*) * * * In the following year we again find Selligue before the academy, requesting that body to appoint a committee to examine the merits of his new system of gas-lighting; his process of distilling bituminous shales on the great scale by means of apparatus, each one of which furnishes from 1,000 to 1,400 pounds of crude oil per day—this being about 10 per cent. of the weight of the shale employed, and being almost all that exists in the raw material; also of his process of separating various products from the crude oil, some of which are applicable to the production of gas, others to ordinary purposes of illumination, and others to different uses in the arts. (*b*) This petition was referred to a committee of three, Thénard, D'Arcet, and Dumas, who reported in 1840. (*c*) * * * In 1838 Selligue obtained a new patent "for the employment of mineral oils for lighting", (*d*) which, it should be observed, claims only to be an improvement upon that of Blum and Moneuse. * * *

On the 27th of March, 1839, Selligue specifies certain additions and improvements to the preceding patent. In alluding to the use of his oils in the treatment of cutaneous diseases he speaks of the three large establishments for the distillation of bituminous shale which he has erected in the department of Saône et Loire, and mentions the fact that the oil (crude) is furnished at the rate of about 2 cents (10 centimes) per pound. (*e*) * * * The clearest of all Selligue's specifications, however, is that of the patent granted him March 19, 1845, for the distillation of bituminous shales and sandstones. (*f*) After describing the various forms of apparatus used in distilling, into one of which superheated steam was introduced, he enumerates the products of distillation as follows: I. A white, almost odorless, very limpid mineral oil, somewhat soluble in alcohol, which may be used as a solvent, or for purposes of illumination in suitable lamps. II. A sparingly volatile mineral oil of specific gravity 0.84 to 0.87, of a light lemon color, perfectly limpid, almost odorless, never becoming rancid, and susceptible of being burned in ordinary lamps, of constant level (à réservoir supérieur), with double current of air, a slight modification of the form of the chimney and burner being alone necessary. This oil can also be mixed with the animal or vegetable oils. Oils thus prepared do not readily become rancid, nor do they congeal easily when subjected to cold. III. A fat mineral oil, liquid at the same temperature as olive oil. This oil contains a little paraffine; it is peculiarly adapted for lubricating machinery, and has an advantage over olive and other vegetable oils, or neat's-foot oil, in that it preserves its unctuosity when in contact with metals and does not dry up. It saponifies easily, and forms several compounds with ammonia. IV. From the oils I, II, and III I extract a red coloring matter which can be used in various arts. V. White crystalline paraffine, which needs but little treatment in order to be fit for making candles. This substance does not occur in very large proportion in the crude oil, and the proportion varies according to the different mineral substances upon which I operate. There is but little of it in petroleum and in the oil obtained from bituminous limestone. I often leave a great part of the paraffine in the fat oil and in the grease, in order that these may be of superior quality. VI. Grease. This grease is superior to that of animals for lubricating machinery and for many other purposes, since it does not become rancid, and remains unctuous when in contact with metals. VII. Perfectly black pitch—very "drying"—suitable for preserving wood, metals, etc. VIII. An alkaline soap obtained by treating the oils with alkalies. IX. Sulphate of ammonia. X. Manure prepared by mixing the ammoniacal liquor or the blood of animals with the crushed fixed residue (coke) of the shale. XI. Sulphate of alumina from the residue of the shale. In describing the methods of purification proposed by Selligue we shall make no attempt to follow their various details, our limited space compelling us to content ourselves with only the broadest generalities. Selligue sets forth at length two methods:

1st. A cold treatment, which consists in agitating the oils with sulphuric, muriatic, or nitric acid. This agitation should be thorough, he says, and should be continued for a longer or shorter time, according to the nature and quantity of the matter treated. Here follows a description of his agitators. After several hours repose the oil may be decanted, except from muriatic acid, in which case more time and a larger amount of acid is required. After the oil has been thus separated from the deposit of tar, the acid remaining in it must be neutralized by means of an alkali. "I prefer," says Selligue, "to employ the lye of soap-boilers marking 36° to 38°, since it is easy of application and produces a sure effect. I thus precipitate together the coloring matter and the tar, which would otherwise have remained in the oil. The oil is then decanted; if it is the first distillation of the crude oil, I do not allow the mixture to subside entirely, preferring to leave a portion of the alkali mixed with the oil and to distill off only three-fourths of the latter. * * * When the soda lye—in quantity slightly greater than is necessary to neutralize the acid—is added, the liquid must be agitated violently, in order that each particle of the oil may be brought in contact with the alkali; and this agitation must be continued until the color of the oil undergoes change. The oil becomes less odorous and less highly colored after each such 'cold treatment'. After having been allowed to separate from the lye, the oil is decanted off; if it has not lost much of its color the process has been badly conducted. It must be stated that the oil must not be agitated several times with the alkali, for by so doing the dark color of the oil would be restored. * * * As for the residues of the soda treatment", continues Selligue, "they should be allowed to stand at rest during some days beneath a portion of oil, which will protect them from contact with the air. The clear lye at the bottom being then drawn off may be used for other operations, while the remainder is a soap containing excess of alkali. By adding to it a little grease a soap can be made, or by adding water grease may be separated. This grease is similar to that used for wagons."

2d. A warm treatment that follows the cold, and consists of a series of fractional distillations—special operations for the purification of the "light stuffs" being resorted to. For the details of these we must refer to the original specification of Selligue—a truly classical document—which should be read by every one interested in the manufacture of coal-oils (or petroleum). (*g*) * * * As for paraffine, Selligue obtained it by subjecting the oil to a low temperature, in order that this substance might crystallize. The mixed oil and paraffine was then thrown on fine metallic filters, through which the oil flowed while the paraffine was separated. Or one may separate the oil, he says, by imbibition, but this occasions a great loss of oil, and also requires more labor.

These successive patents, extending over a period of about fifteen years, show not only that Selligue was a complete master of this department of technology, on the general principles of which but little improvement has since been made, but also that, prior to 1845, this industry had become important and extensive in France.

In England no commercial importance appears to have attached to the paraffine-oil industry until 1850, when James Young and his associates, Messrs. Binney and Meldrum, established the extensive works at Bathgate, from

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a See 7 patents in *Brevets d'Invention*, lxx, 269. Of these patents two are dated 1834, two 1835, and three 1836. For a description of his process of gas-making, see also *Bul. Soc. d'Encouragement*, Oct., 1838, p. 396, or Dingler, lxxi, 29.

b *Comptes-Rendus*, 1838, vii, 897.

c *Ibid.*, x, 861, Dingler, lxxvii, 137.

d *Brevets d'Invention*, lxviii, 395.

e *Comptes-Rendus*, ix, 140; *Ann. der Pharmacie*, v. Wöhler u. Liebig, xxxii, 123.

f *Brevets d'Invention* (N. S.), loi du 5 *Juillet*, 1844, iv, 30.

g A tolerably accurate English translation of this important patent may be found in the specification of A. M. B. B. Du Buisson, 1845, specification No. 10,726 of the English patent office.

the success of which has followed the Scotch paraffine and mineral-oil industry, which, in 1878, produced from 800,000 tons of 2,000 pounds each of shale 30,000,000 gallons of crude oil. From 8,040,000 gallons of this oil was made: (a)

	Value.
500,000 gallons naphtha	$40,000
4,000,000 gallons burning oil	320,000
1,035,000 gallons heavy oil	82,000
200,000 gallons medium oil	16,000
Paraffine	62,000
Sulphate of ammonia, 82 per cent. products	23,000
	543,000

Specific gravity of the naphtha	0.725
Specific gravity of the lamp-oil	0.805
Specific gravity of the medium	0.840

SECTION 2.—SOURCES OF CRUDE PARAFFINE.

Crude paraffine is found fossil in Galicia, Roumania, the Caucasus, the neighborhood of the Caspian sea, and in the Sânpete valley in Utah. In all of these localities, except the last, it is found in a formation that yields petroleum and also contains paraffine. Paraffine is also a constituent of a large majority of the different varieties of petroleum found upon the earth's surface, and also of the asphaltums that occur in injected veins, such as albertite, grahamite, and the asphaltum of Cuba. As a product of destructive distillation paraffine is obtained from all kinds of bituminous coal, shales, lignite, peat, wood, and animal remains, provided the distillation is conducted at a sufficiently low temperature.

The fossil paraffine or ozokerite of Galicia is principally obtained in Boryslaw and Stanislow in the Miocene of the foot-hills of the northern slope of the Carpathians; also at Slanik, in Moldavia, near mines of rock-salt and coal. In 1875 the amount produced in these two localities was about 44,000,000 pounds. The "earth-wax" occurs partly in regular beds and partly in pockets, from which it is obtained in small pieces or masses of several hundred pounds weight. The beds containing the mineral are reached by shafts from 130 to 260 feet in depth, from which the exploitation is carried on by tunnels, as in ordinary mining. These shafts generally pass through gravel and bowlders from 25 to 30 feet, and then through blue loam and plastic clay. In this clay, at a usual depth of from 140 to 150 feet, the "earth-wax" is found in layers of from 1 foot to 3 feet thick, the purest being of a honey-yellow color, and of the hardness of common beeswax. Much of it, however, is in small pieces, which must be separated from the gangue, the smallest pieces being obtained by washing. The purer qualities, on being melted, yield a prime "earth-wax", which is manufactured into "ceresine." The poorer varieties are dark-colored, some of it being soft, containing petroleum, and some of it being hard like asphaltum. These poorer qualities are used for the manufacture of paraffine. Rarely pieces are found which are very compact and as hard as gypsum, fusing above 100° C., and, like many specimens of petroleum, are dichroic—dark-green in reflected light and pure yellow in transmitted light.

As stated above, the crude ozokerite is separated from the gangue by melting and worked into paraffine or ceresine. The "trying" is effected either by direct fire or by steam. In the former case, the ozokerite is placed in iron kettles about one and one-half meter in diameter by one meter in height, melted, drawn off, and the residue boiled with water, when all the ozokerite will rise to the surface of the water. In the latter case the melting is done by steam in the same manner as with paraffine or stearine, and needs no further description. The "tried" ozokerite is clarified by allowing it to settle for several hours and then poured into iron molds. It is shipped in this form, without any further packing, in pieces weighing from 50 to 60 kilograms (110 to 130 pounds). There are principally two kinds of commercial ozokerite, prime and second. Prime "wax" ought to be as free as possible from earthy impurities, and in small, transparent, greenish-brown to yellow pieces; the lighter in color and the more transparent the better it is. "Second wax" is dark brown, almost opaque, occasionally containing a great deal of earthy impurities, and is generally much softer than the prime. Both are used in the manufacture of either paraffine and illuminating oils or ceresine. The manufacture of paraffine from ozokerite is effected by distillation over direct fire from iron retorts with flat bottoms containing from 1,500 to 2,000 pounds. The product of the distillation are: (b)

	Per cent.
Benzine	2 to 8
Naphtha	15 to 20
Paraffine	36 to 50
Heavy (lubricating) oils	15 to 20
Coke	10 to 20

The paraffine is pressed, treated with sulphuric acid and caustic soda, filtered through paper and fine animal charcoal, and made into candles. The naphtha is purified in the usual way, and the heavy oils are sometimes subjected to fractional distillation, but mostly shipped as such to Vienna. The manufacture of "ceresine" consists of the removal of the impurities from the "earth-wax" by the aid of sulphuric acid and animal charcoal; but only the best kinds of ozokerite are used. The different processes are kept secret, and are also protected by patents. In general the ozokerite is melted with concentrated sulphuric acid, and the residue from the manufacture of yellow prussiate pressed, treated again with prussiate residue and filtered. One hundred parts good prime "earth-wax" yield sixty to seventy parts white wax, which in its properties very closely resembles white beeswax, and is called "ceresine". It is either further purified by repeated treatment with acid and prussiate residue, or colored with gamboge or alkanet, and thereby made to resemble common beeswax.

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a *Hübner's Zeitschrift*, 1879, 12; W. B., 1879, 1170.

b This is manifestly a cracking process, and it is evidently a somewhat rude method of treating such a valuable substance. Distillation by steam would be much better.

In the manufacture of ceresine only sulphurous acid and press residues are obtained, the former of which escapes into the air, but might be utilized, thus reducing the cost considerably. The consumption of sulphuric acid in Boryslaw alone is said to amount to 2,200,000 pounds a year. The prussiate residues are obtained from the lixiviation of the crude prussiate in Moravia. Comparatively only a small quantity of earth-wax is worked in Galicia, and is shipped principally to England, Moravia, and Vienna. The ceresine is exported in large quantities to Russia, where it is sold as beeswax, a little of which is melted with it in order to impart to it the characteristic odor. Good ceresine is hardly to be distinguished from beeswax. The best method is the following: 1. Ceresine is not as easily kneaded between the fingers and becomes brittle more readily than beeswax. This test is, however, doubtful if the sample is a mixture of the two. 2. Ceresine is scarcely attacked by warm concentrated sulphuric acid, whereas beeswax is completely destroyed by it. By this test the quantities of beeswax and ceresine can be determined in a mixture of both. In many cases ceresine can be employed in place of beeswax. It is sold at $32 to $40 per 100 kilogrammes (16⅔ cents per pound) in Vienna, whereas the price of the commercial earth-wax varies from $10 to $12 per 100 kilogrammes (5 cents per pound). The whole exploitation of the ozokerite is in the hands of the Jewish population. (*a*)

The ozokerite deposits of Utah have not yet been worked sufficiently to demonstrate their importance. The crude material is of about the consistence of paraffine, and is of a jet black color, and furnishes, when purified, a pure white paraffine.

The question whether paraffine is or is not a constituent of petroleum has been widely discussed. I am not prepared to assert that crystallizable paraffine is a constituent. I have seen crystals of paraffine in petroleum that came from the wells of the Economites opposite Tidioute that I had no reason to suppose had ever been heated, or, in fact, manipulated in any manner, except to be put into barrels; yet I cannot positively assert that such was the case. Amorphous paraffine is certainly a constituent of many petroleums, and is readily obtained where petroleum is carefully distilled until the residue has the consistence of paste when cold. The amount of reduction necessary varies with the source of the petroleum used. A sample from the southeastern border of the Pennsylvania petroleum field was of an amber color, and of nearly the consistence of honey from suspended paraffine. The oil of the Bradford field is remarkable for the amount of paraffine it contains as compared with other oils of the Pennsylvania region. This peculiarity occasions a great deal of trouble with flowing wells, as the pipes become clogged with paraffine so completely as to stop the flow of oil. This is no doubt in part occasioned by the fractional condensation of the paraffine in consequence of the extremely low temperature produced by the rapid evaporation of the more volatile portion of the petroleum when it is relieved from the enormous pressure to which it is subjected in the rock. This extremely low temperature, which has been known to plug a well with ice and to produce ice under the sun of a hot summer's day, evidently condenses the paraffines having the highest melting point, and allows those more fusible to remain dissolved in the oil. (*b*) As regards the practical working of petroleum, it is of little importance whether the paraffine is an educt or a product, for if the paraffine is not already a constituent of crude petroleum, the heat required for distillation develops it. The amount of paraffine, however, that any given sample of petroleum contains or will yield is a matter of the greatest importance if the crude oil is to be made into illuminating oils. The crude oils of Butler and Armstrong counties are much more valuable for that purpose than those of McKean county, because they contain more of the members of the paraffine series of the proper specific gravity for illuminating oils and less of the dense, heavy oils and solid paraffine that have to be cracked before they can be used for illumination.

In 1849 a Mr. Reece obtained a patent for distilling paraffine from Irish peat, and works for its production were established near Ashby. While the method of treating the peat was entirely successful, the enterprise, on account of the small amount of material it was capable of yielding, was a commercial failure. It is proper to state here, however, that acetic acid and ammonia, as well as paraffine, were expected to be obtained in commercially valuable quantities. The following statement will give an idea of the proportion of these articles yielded by the peat. On the first distillation the peat yielded:

	Per cent.
Watery matters	30.614
Tar	2.392
Gases	62.392
Ashes	4.197
	99.595

The watery matters and tar yielded:

	Per cent.
Ammonia	0.287
Acetic acid	0.207
Naphtha	0.140
Volatile products	1.059
Paraffine	0.125

a J. Grabowsky, *Am. Chem.*, vii, 123. Hübner's Z., 1877, 83.

b Various methods have been suggested for removing this paraffine from the pipes. It is only slightly soluble in benzine, and neither acids nor alkalies attack it, and other solvents are equally ineffectual. Metallic mercury has been used, which must act mechanically by its weight. A plan to burn it out of the pipes by supplying a stream of oxygen has been recommended, but what degree of success, if any, attended its use I have not learned. The most common method pursued in the oil region is to pull up the pipes and blow out the plug of paraffine with steam. The pipes are often found plugged solid for hundreds of feet.

Fifty tons of peat yielded 125 pounds of paraffine, an amount too small to admit of a profitable enterprise. (*a*) The peat of Hanover yields more than 300 pounds of paraffine to 50 tons.

J. J. Beitenlohner gives the following results of the manufacture of paraffine from peat-tar. The locality of the peat is not given, nor is the amount of tar yielded:

By fractional distillation:	Per cent.
Crude and chemically combined oil	35. 3
Crude paraffine in mass	48. 2
Coke	10. 4
Gas	6. 1
	100. 0

The results of the purification of the paraffine with sulphuric acid and lye are:

	Per cent.
Paraffine	76. 3
Loss by sulphuric acid	12. 2
Loss by lye	9. 4
Loss by washing	2. 1
	100. 0

The paraffine thus obtained is subjected to distillation, the result being:

	Per cent.
Oils	25. 5
Paraffine	66. 5
Coke	2. 6
Gas	5. 4
	100. 0

The paraffine is then refrigerated and pressed, and from it are obtained:

	Per cent. in winter.	Per cent. in summer.
Coke	21. 6	18. 2
Oils	75. 3	78. 3
Loss	3. 1	3. 5
	100. 0	100. 0

This paraffine is then digested in fuming sulphuric acid, but remains soft and unctuous. (*b*) The distillation evidently cracks it.

In an elaborate research upon the products of the dry distillation of Rhenish shale and Saxony and Thuringian brown coal, H. Vohl gives the following table, showing the comparative value of shales, brown coal (lignite), and peat as sources of paraffine: (*c*)

Raw material.	Light oil or photogen: sp. gr. 0.820.	Heavy gas or lubricating oil: sp. gr. 0.860.	Paraffine.	Asphalt.	Creosote and loss by refining.
Shale:	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*
English	24. 285	40. 000	0. 120	10. 000	25. 595
From the Romerickeberg mine	25. 688	43. 000	0. 116	12. 030	19. 166
From Westphalia	27. 500	13. 670	1. 113	12. 500	45. 300
From Oedingen on the Rhine	18. 333	38. 333	5. 000	13. 333	25. 001
Brown coal from—*					
Aschersleben, No. I	33. 500	40. 000	3. 330	18. 100	5. 070
Aschersleben, No. II	20. 500	43. 600	6. 510	19. 567	9. 823
Frankenhausen	33. 410	49. 063	6. 730	17. 321	2. 476
Münden	17. 500	26. 213	5. 063	18. 679	32. 545
Oldisleben	17. 721	26. 600	4. 430	17. 526	33. 722
Cassel, No. I	16. 428	27. 142	4. 286	14. 290	37. 853
Cassel, No. II	16. 666	21. 052	5. 263	13. 163	43. 855
Bavaria (von der Rhon)	10. 625	19. 375	1. 250	16. 900	51. 850
Tilleda	16. 666	18. 055	4. 444	11. 111	49. 722
Brown coal from—Continued.	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*
Harbke, No. I	15. 555	11. 111	3. 555	22. 222	47. 555
Harbke, No. II	16. 666	11. 765	2. 941	20. 000	48. 627
Stockheim, near Düren	17. 500	26. 630	3. 260	16. 900	36. 710
Bensberg, near Cologne	16. 360	19. 535	3. 463	13. 173	47. 461
Peat from—					
Celle	34. 600	36. 000	8. 010	11. 540	9. 850
Coburg	20. 625	26. 578	3. 125	17. 190	32. 482
Damme	19. 457	19. 547	3. 316	17. 194	40. 486
Neuenhaus, heavy	17. 983	19. 640	5. 360	16. 071	40. 945
Neuenhaus, light	14. 063	18. 230	5. 209	18. 750	43. 748
Zurich	14. 400	8. 666	0. 424	42. 424	35. 086
Russia (Rostokina, near Pasjkina)	20. 390	20. 390	3. 367	25. 658	30. 195
Bottross, in Westphalia	11. 000	19. 489	2. 256	26. 000	41. 255
Neuwedel, Prussia	14. 130	18. 266	3. 102	28. 260	36. 241

* These "brown coals" are lignites, nearer peat than coal.

a Frederick Field, J. S. A., xxii, 349, 411; *Am. C.*, v, 169. *b* *Jour. de l'Éclairage au Gas*, 1872, No. 5, Am. C., ii, 315. *c* W. B., iii, 459.

The paraffine oil industry of Scotland has already been noticed. Its present success, notwithstanding the low price of petroleum products, is mainly due to the heavy oils and paraffine produced. While I cannot indorse all the claims that are made for Mr. Young as the first inventor, as the process which he patented corresponded to that used by Selligue many years before, there is no question that he deserves the credit of having placed the paraffine industry on a solid commercial basis in Great Britain at a time when the discovery of petroleum in such vast quantities in Canada and the United States would seem to have rendered such an undertaking impossible.

At the date (1860) at which petroleum was first an article of commercial importance, paraffine and paraffine oils were being produced in the United States and Great Britain from the so-called Boghead coal, albertite, and grahamite, together with several rich cannel coals. The deposits of the three minerals above mentioned have been worked out. The last establishment in the United States using anything but petroleum was the Union Coal and Oil Company, of Maysville, Kentucky, which was operated upon the rich cannel coal of Cannelton, West Virginia, on the Great Kanawha river. It ceased operations in 1867. The deposit of Boghead mineral was worked out in 1872, since which time the extensive paraffine oil works of Scotland have been run on shale. On the continent of Europe, in Saxony, Thuringia, and Austria, an extensive and very valuable industry is conducted with shale and brown coal as the raw material. In the United States, beside our deposits of cannel and bituminous coals of enormous extent, we have thousands of square miles of shales that will furnish millions of barrels of distillate for use after our 200,000 square miles of petroleum fields shall have been exhausted.

SECTION 3.—PREPARATION OF PARAFFINE.

The preparation of paraffine from petroleum has already been described on page 165, and the treatment of the crude oils distilled from shale or coal is substantially the same, with the exception that more sulphuric acid and more numerous distillations are employed. While crude shale oils and petroleum are very similar fluids, the shale oil is much more impure and more expensive to refine. Distillation and treatment with sulphuric acid and soda lye are, with some variation in the details, the methods upon which the technologist in paraffine must rely. The subsequent treatment of the crude paraffine scales is subject to considerable variation, and an article quite variable in its properties is the result. The ordinary method of purification consists in dissolving about 2,000 pounds of crude paraffine in 80 gallons of "C" naphtha by heat, refrigerating in shallow metal pans and pressing; but this method is attended with considerable loss of naphtha, and some danger from accidental ignition. To obviate this a process was invented for treating the paraffine cold, by which it was either pulverized and then dissolved in naphtha, or the cake and naphtha were ground together into a paste and then pressed. After this grinding and pressing has been repeated a sufficient number of times, the solid wax is melted in a still with steam blown in until no naphtha comes over with the condensed water. From 3 to 5 per cent. of animal charcoal is then added, and while the mass is kept melted the charcoal is allowed to settle. As the finest particles of charcoal remain diffused through the wax, the whole is filtered hot through a wire-gauge filter, which is lined with flannel and filter paper, the filtrate passing as colorless as distilled water. (*a*)

The use of these successive solutions in naphtha is to remove the fluid oils from which the paraffine first crystallizes, which are more readily soluble in the naphtha than the paraffine itself. Mr. John Fordred in 1871 sought to accomplish the removal of these oils by kneading the paraffine with or in a slightly alkaline solution. After melting and clarifying a ton of paraffine and casting it into thin cakes of about ten pounds each, these cakes are placed in a bag, end to end, and warmed until they become plastic. The bag is then placed in a kneading machine, which is supplied with a solution of equal parts of soft soap and water at a temperature of about 100° F. On setting the machine in motion the oil and coloring matter are dissolved in the soap solution. Solutions of carbonated and caustic alkalies, both alone and mixed with soap, rosin soap, and even warm water itself, are found to answer the purpose. (*b*) Another patent claims economy in operation and safety in the use of material. A tank 12 by 6 by 2½ feet is provided with partitions, which separate it into V-shaped cells, 2½ inches wide at the top and 2 inches wide at the bottom. These cells are 1 inch apart, and start 9 inches from the top of the tank and stop 2 inches from the bottom. A grating is provided, that rests upon the top of the cells, the bars of which are 1½ inches apart. Free or closed steam-pipes are placed in the bottom of the tank, and water is filled in to a depth of 6 inches. Crude paraffine is filled into the cells and the grating secured to prevent its floating. Water is then run in until it rises to within two inches of the top of the tank, and steam is turned on until the temperature reaches within 10° of the melting point of the paraffine being treated, when it is turned off and the entire mass is allowed to become of a uniform temperature. Steam is then again turned on and the temperature very slowly (through at least 4 hours) brought to within 2° of the melting point of the paraffine, when the soft portions that have risen are skimmed off. The water is then drawn off to the top of the cells and the paraffine is melted and allowed to cool slowly through the night, when the operation is repeated. This is continued until paraffine is obtained of the required hardness, while the soft portions are returned to the crude paraffine. The hard paraffine is then melted with 7 per cent. of powdered commercial ivory-black in a steam-jacketed pan for four or five hours, until the

a Patent of Ed. Meldrum, No. 1646, 1867.

b Patent No. 1858, 1871.

whole of the ivory-black is precipitated, when it is drawn off and cast into cakes. (*a*) Another process requires the paraffine to be clarified by settling and being cast into cakes, which are allowed to cool very slowly, in order that the crystals may form of large size. The cakes are then placed on tiles or other absorbent material and heated nearly to their melting point. The fluid and easily fusible portions are melted and flow from the crystals and are absorbed by the tile. This process may be repeated as many times as may be desired, and the paraffine may then be bleached with bone charcoal or by any other means. (*b*)

By whatever method the paraffine may be freed from the fluid and the fusible impurities, it is not white, and is afterward subjected to a bleaching process. One method has already been described; another requires that the melted paraffine be agitated in a tank by a current of air with from 5 to 10 per cent. of strong sulphuric acid, care being taken to remove the sulphurous acid evolved by a suitable ventilating apparatus. This agitation is carried on for several hours, until the experience of the operator shows the treatment to be sufficient, when the tarry mass is allowed to subside through several hours. The still slightly-colored paraffine is then digested with animal charcoal, the last traces of which are removed by filtering through a steam-jacketed filter. The apparatus by which this filtration is performed is thus described by L. Ramdohr in Dingler's *Polytechnic Journal*, 1875:

After paraffine has passed through all other stages of the purifying process, it must finally be decolorized by means of charcoal. The use of a permanent filter (eines stehenden) filled with granulated charcoal is not to be recommended for many reasons.

The filtering process must take place at a temperature of not less than from 70° to 80°; the filter also must be heated with steam, which, on account of the large dimensions, would require incommodious and expensive apparatus. But particularly against the use of granulated charcoal stands the fact that a greater part of the paraffine is retained by the charcoal, which can only be partly collected again through burning of the coal, which always is united with a considerable amount of decomposition (products) of the paraffine. But paraffine is so valuable that its manufacture cannot suffer such a great loss in material. Consequently the decolorization of paraffine takes place in a much simpler way with a fine, pulverized, and, where it is possible, freshly-heated charcoal, which usually becomes mixed with the paraffine by agitation with a wooden mixer, and the greater part of it thereupon very quickly settles to the bottom.

The fine particles of coal, notwithstanding, remain suspended a long time in the fluid paraffine, and are even not entirely removed after a day's rest, so that the paraffine must be completely cleared by filtration through paper. Paraffine that is not filtered is of a smutty gray color. In most of the paraffine manufactories I have found the arrangement of filter paper to be very primitive, and the mixing apparatus separated or divided by the filtering apparatus, so that a continuous scooping over of the paraffine to be filtered upon the filter and a continuous addition of the latter was necessary. Consequently, I give the following description of a mixing and filtering apparatus constructed by me, which I have used in two instances many years with the best results.

This has the following peculiarities in its arrangement: 1. The mixing of the paraffine with bone-black does not take place by the hand or through a mechanical stirring contrivance, but through a warm current of air previously blown into the apparatus. 2. The paraffine treated with bone-black flows of itself into the filter paper placed in a glass funnel, and after the influx has once been regulated the control of the entire apparatus by the workman is scarcely anything at all. Even if at times less penetrable paper should accidentally be placed in the filter, this, from the attention on the part of the workman, cannot easily cause an overflow of the paraffine, while the greater or lesser penetrability of the paper is easily observable during the first half hour by the regulation of the inflowing stop-cock, and this must be considered by the workman. 3. The whole apparatus is heated by waste steam. 4. The mixing and filtering apparatus occupy little room, and, *e. g.*, 25 hundred-weight of paraffine can be easily mixed and filtered in twenty-four hours.

In Figs. 44 and 45 are illustrated: A. The mixing apparatus. B. The filtering apparatus. The steam first enters the filtering apparatus, and then passes through the mixing apparatus into the open air.

The mixing apparatus A consists of a wrought-iron chest, with a turned cast-iron flange, covered with iron cement, in which are three openings for the admission of three cast-iron mixing-kettles. These kettles are fastened to the flange of the steam-chest by a few screws, in order to prevent any displacement which an insecurity of the discharging vessel would cause. The kettles, with the steam-chest, are rendered steam-tight (der dampfdichte Abschluss des Kessels) in the simplest manner by a band of rubber placed beneath the rim of the kettle.

About 75^{mm} above the deepest parts of the bottom of the kettle is cast a support 25^{mm} wide, of such a length that it, with its forward end provided with screws, projects through the tin face-plate of the steam-chest, perhaps 25^{mm} wide. At this point about 3^{mm} thickness of tin is strengthened by a disk fastened by sunken rivets and of 15^{mm} thickness, and provided with four bolt-holes for the reception of screw-tacks. From the outside a flange is tacked upon the end of the kettle support that is provided with screws, and by underlaying with hacked hemp and intimately mixed red-lead cement against the solidly-built face of the steam-chest is so placed that the four screw-holes in the flange correspond exactly with those of the opposite inner disk. After this flange is firmly drawn the end of the kettle support, which is plainly turned off or polished, shall project over the flange 2 to 3^{mm}. Now, four screw-tacks, which are supported by a six-angled truss, are brought into four screw-holes, which are at hand to receive the same, and drawn firmly and steam-proof against the outer flange, and each kettle support is provided with a 25^{mm} wide cast-iron stop-cock. In the distribution of crude paraffine, and, above all, where prepared paraffine is to be filtered, this invention applies equally well, as it completely soaks through several layers of uniform unsized paper by the avoidance of all cements.

It is recommended to provide the surfaces turned upon the lathe with fine circular grooves. In the lower portions of the steam-chests lie six pieces of thinly-drawn crude copper plates (without soldered edges) which are contrived after the manner of the tubes of locomotive boilers, and are so joined outside of the chest by cast-iron knees that they form a long pipe or hose, heated by steam, in which the air to be used for the mixing of the charcoal and paraffine is heated. The exit of this pipe stands diagonally over the mixing boiler in combination with a running tube or siphon, which, through the middle of the boiler, reaches almost to the bottom of the same, being sent off from the copper pipe through a stop-cock in diminished size. It is self-evident that the main pipe for the warmed air from the steam-boiler is to be protected from cooling.

The filter apparatus B consists first of two polished chests, partially within each other, with a common front wall. The latter also will not be touched by the steam, and this arrangement will rest or touch entirely upon the ground, in order, on this side, where the workman is busy for the most of the time, not to have a too strongly heated surface, and to make the real filtering apparatus as comfortably accessible as possible. Otherwise, were there here a double wall filled with steam, then certainly this must be protected from a too strong radiation of heat by a strong wall built in front 120^{mm} thick, and this would detract from the service of the filtering apparatus. Beside, the

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a Litchford and Nation's patent, No. 890, 1872. *b* Hodges' patent, No. 3241, 1871.

arrangement chosen insures a cheaper and simpler construction. Then the greater extent of surface can be made impermeable to melted and heated paraffine only with the most extraordinary difficulty (and perhaps not at all); but all loss of paraffine by incompactness or insecurity is to be particularly avoided, so the inner filtering chest to serve for the reception of paraffine must be made of cast-iron in one piece.

The attachment of the steam-jacket is simple and plainly shown in the drawing. The bottom of the cast-iron filtering chest is inclined toward the front, and at the same time from both sides toward the middle; at the deepest point there is an exit tube, with stop-cock for the drainage of the prepared paraffine. In the interior the filtering chest has a projecting brim of perhaps 50^{mms} breadth, which on the rear wall, and at the same time on both sides, serves for the formation of steam space. Upon this edge rest 8 pieces of wrought-iron filter supports, each of which is capable of receiving two glass filters; thus there are 16 filters arranged in rows always in operation. The funnels are made of glass; because it more easily preserves the absolutely necessary cleanliness than if they were made of white tin. One need not fear the destruction of the glass if there is the proper amount of foresight shown on the part of the workman. In about twelve years there were scarcely one or two broken by me. In the midst of the filtering chest, along its length and 50 to 60^{mm} above the glass funnels of the paraffine-distributing pipe, there is a pipe 40^{mm} wide, closed at both ends, communicating through three supports with the corresponding terminal stop-cocks of the mixing kettles, and connected to both sides with eight small cast-iron stop-cocks of 4^{mm} width attached to a wrought-iron pipe. The small stop-cocks are screwed on, and for this purpose small pieces of wrought-iron have been placed with hard solder in the proper places on the distributing pipe.

The mouths of the small stop-cocks do not lie perpendicularly over the middle of the filter, but are nearly in the middle of a side, in order to prevent the perforation of the filter-point by droppings. The paper used for filtering is a thin, but tolerably firm, unsized pressed paper; it is broken after the manner of bent filters. A sheet 45 by 37^{mm} (one 40 by 40^{mm} would be more convenient) makes a a filter that will serve comfortably for the filtration of about a hundred-weight of paraffine.

When working day and night I have always had the filters renewed after using twelve hours. The very little paraffine that remains in the paper is recovered.

It is recommended to surround the warm, radiating surface of the mixing and filtering apparatus with a simple and appropriate non-conductor. This is attained by inclosing the apparatus, and only the front wall of the filter chest is provided with a wooden jacket for securing an isolated stratum of air.

The covering of the apparatus is not shown in the illustration, in order not to interfere with its clearness; likewise the conveyance of the water which falls down from the steam in both apparatus (and which forms in the best of steam spaces) is not noted, since their position depends entirely upon local surroundings.

Finally, a word concerning the restoration of fresh bone-black and the treatment of that which has been used. It is known that the fresher charcoal is the more energetically it acts. In very large paraffine factories it is used on this account to prepare it from the coal itself, and by use it settles.

Comparatively speaking, very little can be restored with profit, as it is used even in the largest paraffine factories. In a business of less extent one will easily see from this that it is at least unprofitable to buy the powdered preparation of coal from the charcoal factories, because one receives with it in most cases smut and dust from the sifted granulated charcoal, and has not the slightest guarantee for the quality and freshness of the preparation. I have always, on this account, secured from a neighboring charcoal factory the small quantity of 100 kilograms of freshly prepared granulated and dust-free charcoal and allowed the pieces of coal to be immediately reduced to a fine powder for use in a simply constructed pulverizing cylinder (in Figs. 46 and 47). If one has not a charcoal factory in the immediate vicinity, and has not the certainty of obtaining the granulated coal entirely fresh at all times, then it is well worth the while to buy the pieces of coal in larger quantities and to allow the same to be thoroughly heated in kettles again, previous to the use of the coal which has been just pulverized.

The pulverizing cylinder (Figs. 46 and 47) is made of cast-iron (750^{mm} long and 500^{mm} in diameter) and revolves with riveted wrought-iron pegs in corresponding metallic holes in the facing; in the surface of the jacket or cover there is an opening for filling and emptying made close with gum. The cylinder is revolved best in slow revolutions (at most but two turns per minute). Within the cylinder there lies another massive cast-iron cylinder 120^{mm} in diameter, with a length equal to that of the drum. In twelve hours an apparatus of this size will pulverize perhaps 25 kilograms in the finest manner. These dimensions can be considerably increased without disadvantage.

The bone-black I have mostly used in quantity, not over 3 per cent. of the weight, and the paraffine retained by the same amounts to about the same weight. This silt from the powdered coal and paraffine is first heated together in a thick-walled kettle with return steam, whereby a greater part of the paraffine is separated into a clear liquid, which is scooped up with a shallow ladle and placed directly upon the filter paper.

The silt which has become thin is put in a large iron kettle, in which it, with the least quantity of water (from six to eight parts), is thoroughly cooked out over an open fire and under an active stream of steam, which is used from time to time. By the cooling of the mass almost all of the paraffine separates upon the top of the water as a firm but gray-colored layer, which is taken off, melted, and filtered through the paper with the other materials. A repeated boiling of the silt is seldom necessary, and this second operation almost never pays, because of the cost of the fuel in obtaining the paraffine. The powdered coal still so obstinately retains a very small percentage of the paraffine that this must be driven off by heating the coal, if the latter is to be again used as a decolorizer, or even if it is to be useful in the manufacture of acid phosphate of lime—superphosphate.

With this view I cause it to be thoroughly heated in an inclined cast-iron retort of about 2^{m} to 3^{m} long and 800^{mm} wide, and cross-cut almost elliptically, which is provided with an appropriate receiver for the condensation of the paraffine vapor. (This vapor never remains even at the lowest possible melting point of paraffine undecomposed, but yields paraffine of a low-melting point and oil as the product of decomposition). The paraffine that has been boiled out in shallow wrought-iron chests of perhaps 12^{mm} height and 1^{m} length, whose bottom conforms to the form of the retort, and both of whose sides have small and appropriate stop-cocks, is passed into the retort, and after the ensuing evaporation of all the paraffine (which is instantly known by the cooling of the discharge pipe of the retort) during the heating is left therein four to six hours long for the partial cooling.

Then the cast-iron chests, of which two are placed behind each other in the retort, are taken out and immediately covered with an appropriate tin cover, which is everywhere made close by a covering of clay, and the heated coal-dust is left standing therein until it has become perfectly cooled.

The taking out of the retort, the putting on and sealing of the cover, must take place as quickly as possible, in order to prevent the partial reduction of the coal to ashes. (*a*)

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a Dingler, ccxvi, 244.

Powdered fuller's-earth, marl, clay, or any similar substance, mixed with melted paraffine and allowed to subside, will deprive it of color, and the paraffine adhering to the subsided particles may be separated by heating with steam and agitation. (*a*) The successful use of these natural, insoluble silicates led to experiments upon the use of artificial silicates of the alkaline earths. For this purpose silicate of magnesia was found to answer all requirements best. This material is formed by the reaction of solutions of sulphate of magnesia and silicate of soda, the resulting silicate of magnesia being thoroughly washed and dried by steam heat. It is then added to the melted paraffine, and after it has subsided and the paraffine has been drawn off the residue is treated with dilute sulphuric acid. When the paraffine separates and rises to the surface the silica is precipitated, and the solution of sulphate of magnesia lies between them. The paraffine is removed, the solution of sulphate of magnesia is washed from the silica, and the silica is dissolved in caustic soda. It will thus be seen that the material is continually renewed with the addition of sulphuric acid and caustic soda. (*b*) It is found in using these silicates, whether natural or artificial, that a red heat destroys their action, and also that they must be used at such a temperature that the water of hydration is expelled, the coloring matter apparently taking its place. Hence, if the silicate is applied at a temperature only a few degrees above the melting point of the paraffine, it will have no action upon it until the temperature has been raised above that sufficient to expel the water. (*c*)

Another method which has been suggested for the removal of the oils from the soft paraffines consists in melting them with from 5 to 10 per cent. of oleine and cooling and pressing. Paraffine is insoluble in oleine. The mineral oils dissolved in oleine are separated from it by distillation, the former distilling at 220° C. and the latter at 280° C. (*d*) Bisulphide of carbon has also been used for this purpose. (*e*)

Although great efforts are made by all manufacturers of paraffine to prepare the wax of a beautiful pearly whiteness, it is a well-known fact, particularly among the manufacturers of continental Europe, that this freedom from color is not permanent for a long period. It is probable that paraffine obtained through the careful distillation of petroleum is purer and less liable to change than that made from distillation of shale or brown coal. Paraffine is often colored for candles and other purposes. As the beautiful colors produced from aniline are insoluble in paraffine, they are first dissolved in stearine, and the stearine is then melted into the paraffine; the color can be recovered, however, by melting the mixture and passing it through a filter. Two per cent. of stearine will give a clear pink color, and 5 per cent. a full crimson. Blue may be obtained with indigo, red with logwood, green with the two mixed and also with indigo and saffron, orange with logwood and saffron, and yellow with saffron. These colors may be readily incorporated with the mass by grinding a small piece of the paraffine with the color and then working it into the mass while hot. (*f*) To color paraffine black it is recommended that the wax be digested with the fruit of the *Anacardium orientale*, which contains a black fluid vegetable fat that combines with the paraffine and does not injure its illuminating properties.

SECTION 4.—PROPERTIES OF PARAFFINE.

Crude fossil paraffine from Galicia is brown, greenish, or yellow, translucent at the angles, with a resinous fracture. It is usually brittle, and when softened can be kneaded like wax, becoming dark on exposure to air. It becomes negatively electric and exhales an aromatic odor with friction. It melts at 66° C. (149° F.), but its illuminating power is such that 754 ozokerite candles equal 891 of ordinary paraffine, or 1,150 of wax. In 1871 Mr. John Galletly examined a paraffine from Boghead coal which melted at 80° C. and had a boiling point near the red heat, and which therefore presented great difficulties in the way of determining its vapor density. Distillation appeared to convert about half of it into liquid hydrocarbons, but the portion that remained solid after crystallization from naphtha retained its melting point unaltered. This specimen followed the general rule that paraffines from different sources diminish in solubility as the temperature increases at which they melt. The following illustrates this point:

Melting point.	Solubility in 100 c.c. of benzole at 18° C.
Deg. C.	*Grams.*
35.0	133.0
49.6	6.0
52.8	4.7
65.5	1.4
80.0	0.1

a Fordred, Lamb & Sterry's patent, No. 610, 1868.
b Smith & Field's patent.
c Frederick Field: *On the Paraffine Industry*, J. S. A., xxii, 349; Am. Chem., v, 169.
d P. Wagerman, Poly. C. Bl., 1859, 75.
e E. Allan, Dingler, cxlviii, 317; Poly. C. Bl., 1858, 1033.
f Eng. Mech., xxiii, 259.

Although only one part of the paraffine melting at 80°, dissolved in 1,000 of benzole at 18° C., it mixes with it in all proportions above its melting point. The densities of paraffines appear to increase with their melting points, but with specimens having the same melting points it is somewhat difficult to obtain the same results.

The following are numbers obtained with paraffines from Boghead coal: (*a*)

Melting point.	Specific gravity.
Deg. C.	
32.0	0.8236
30.0	0.8480
40.5	0.8520
53.3	0.9110
53.3	0.9090
58.0	0.9243
59.0	0.9248
80.0	0.9400

In 1878 E. Sauerlandt examined the relation of the melting point to the specific gravity of paraffines from ozokerite with the following results: (*b*)

Melting point.	Specific gravity.
Deg. C.	
56	0.912
61	0.922
67	0.927
72	0.935
76	0.939
82	0.943

Sauerlandt separated his paraffines by using solvents.

Sulphuric acid attacks all the paraffines, provided the temperature is sufficiently high. It is further observed that this acid more readily attacks the paraffines with high boiling points than those the boiling points of which are lower. The carbon separated from the paraffine melting at 80° C. by the action of sulphuric acid is in so fine a state of division as to pass through filter paper. Chlorine and nitric acid both produce substitution compounds with many specimens of paraffine, but the products are by no means uniform. (*c*)

It is not an infrequent occurrence to find samples of paraffine mixed with stearic acid and stearic acid containing paraffine. As these mixtures are made legitimately, and also for purposes of adulteration, it therefore becomes necessary to determine their constituents. Any attempt to determine the constituents of such a mixture by determining the density would of course be futile, as the density of neither paraffine nor stearic acid is constant. R. Wagner has proposed the following method, which may be used either qualitatively or quantitatively: Not less than 5 grams of the mixture are taken and treated with a warm solution of hydrate of potash, which must not be too concentrated. A soap is formed with the stearic acid, while the paraffine remains unaltered. Salt is then added until the soap separates as a soda soap and takes down the paraffine with it. The soap is thrown on a filter and is washed with cold water or very dilute ethylic alcohol. The salt is first washed out, and then the soap, finally leaving the paraffine on the filter, which is dried at a temperature below 35° C., care being taken not to fuse it. The paraffine is then carefully dissolved from the filter with ether by repeated washings and the solution carefully evaporated in a weighed porcelain crucible in the water-bath at a low temperature. The residue, consisting of paraffine, is then weighed, and the stearic acid estimated by difference. (*d*)

E. Donath saponifies the mixture with potassa and precipitates with calcium chloride. The calcium soap is washed on a filter with hot water and dried at 100° C. Part of it, after powdering, is extracted with petroleum ether, the extract evaporated at 100° and weighed, when the residue represents the paraffine. (*e*)

The most approved method of determining the melting point of paraffine consists in throwing a chip of paraffine on hot water and allowing it to melt. Then the water is slowly cooled, and the temperature is noted at which the globule of paraffine loses its transparency.

It has been found impossible in the amount of time that I have been able to devote to this portion of the subject to call attention to all of the great number of specific investigations that have been made upon paraffine, and the difficulty of attempting an exhaustive discussion of the subject is increased by the obscurity of the nomenclature. Paraffine in the United States and in the languages of continental Europe is used to signify the solid hydrocarbons obtained in distillates made at low temperatures, but in England the word has been given a

a *Chemical News*, xxiv, 187.
b *Hübner's Zeitschrift*, 1878, 81; Dingler, ccxxxi, 383.
c *Chemical News*, xxiv, 187.
d *Ibid.*, xxvii, 16.
e Dingler, ccviii, No. 2, *Am. Chem.*, iv, 196.

much wider signification, it having been applied to all of the fluid products of such distillation belonging to the marsh-gas series (C_nH_{2n+2}). It appears to me probable, however, that among the solid products to which this name is applied there are to be found the higher members of the series C_nH_{2n}, as well as the series C_nH_{2n+2}, the original substance to which Reichenbach gave this name belonging to the latter series. Among other facts which lend strong support to this opinion is the readiness with which some of the paraffines are attacked by reagents, forming substitution compounds, while others are, true to their name, nearly destitute of affinity. A. G. Pouchet acted on paraffine with fuming nitric acid and obtained an acid which he called paraffinic acid. Analysis of this acid, and also of its salts, showed its composition to be $C_{24}H_{48}O_2$, which indicated that the paraffine had a composition $C_{24}H_{50}$. (*a*) The proof seems equally convincing that the paraffine melting at 80° C. examined by Galletly belonged to the series C_nH_{2n}. It is therefore to be concluded that the opinion advanced as long ago as 1856 by Philipuzzi, that commercial paraffine may be separated into a number of bodies differing in boiling points, is correct, and that definite knowledge regarding the constitution of paraffines from different sources awaits further investigation.

CHAPTER V.—SUBJECTS OF INTEREST IN CONNECTION WITH THE TECHNOLOGY OF PETROLEUM.

SECTION 1.—"CRACKING."

The importance of that reaction which has been technically termed "cracking" scarcely admits of exaggeration. To assert that it is essentially destructive distillation, and that the results of its action are oils of decreased density, the decrease dependent upon the extent to which it obtains action, explains neither the nature of the reaction nor the importance of its effects. In the elaborate report upon petroleum made by Dr. J. Lawrence Smith to the judges of the Centennial Exposition he claims that the phenomena attending the destructive distillation of petroleum were first observed by Professor B. Silliman, jr., and noted by him in his famous report of 1855. (*b*) Professor Silliman says:

> The uncertainty of the boiling points indicates that the products obtained at the temperatures named above were still mixtures of others, and the question forces itself upon us whether these several oils are to be regarded as *educts* (*i. e.*, bodies previously existing and simply separated by the process of distillation), or whether they are not rather produced by the heat and chemical change in the process of distillation. The continued application of an elevated temperature alone is sufficient to effect changes in the constitution of many organic products evolving new bodies not before existing in the original substance.

When consideration is had of the knowledge possessed by chemists concerning petroleum and similar substances at the time Professor Silliman made this unique and original investigation the above paragraph is properly regarded as remarkably sagacious and suggestive. No one in 1855 knew whether native petroleum was a homogeneous fluid decomposed by distillation, as are fixed oils, or a mixture of a great number of fluids separated by distillation, as it really is. Professor Silliman's question remained unanswered until Pelouze and Cahours, and later Warren and Storer, attempted to ascertain what manner of substance petroleum really is. Warren and Storer published their results in 1865, (*c*) and showed that they had succeeded in isolating, in a state of purity, portions of the members of three homologous series of hydrocarbons. Two of these series were isomeric, but the boiling points of the corresponding members of the two groups were about 8° C. apart. Professor J. D. Dana has regarded these hydrocarbons as educts, and has placed them in his system of mineralogy in their proper place as natural, not artificial substances. The fact that they have been isolated in such a degree of purity that considerable quantities have been obtained having a constant boiling point, a constant chemical composition, and furnishing accurate results on the determination of their vapor densities, furnishes all the testimony that chemists can reasonably ask regarding the question whether they are educts or products. The analogy found to obtain between these constituents of petroleum and those of the distillates from albertite, Boghead mineral, cannel coal, and lime soap made from menhaden oil has been considered by some chemists to indicate that, whereas the constituents of these distillates are the constituents of products of destructive distillation, petroleum must be destructively distilled in order to furnish them. Might not these unquestioned facts be so interpreted as to regard petroleum itself as a product of destructive distillation, and the similarity of these fractional distillates be also regarded as an additional proof that all of these products of a similar process, acting on similar materials, are very complex mixtures of compounds

a C. R., lxxix, 320; J. C. S., xxviii, 50. *b* *Am. Chem.*, ii, 18. *c* Mem. A. A. (N. S.), ix, 135; see also page 54.

of carbon and hydrogen that are related to the petroleum as *educts*, and not as *products?* I think all of the phenomena connected with this subject are most satisfactorily explained upon this hypothesis.

I quote the following paragraph from the paper read by A. Bourgougnon at the meeting of the American Chemical Society, held September 7, 1876: (*a*)

During the distillation the products are more and more heavy until the heat produced decomposes the oil in the still; then the oil is dissociated, and by this dissociation, or "cracking", lighter and also more inflammable products are obtained. At the same time this decomposition is accompanied by a formation of carbon, which is deposited in the still, and gases of a very offensive odor pass off with the oil.

This is the first instance that has come under my notice in which this very proper term (*dissociation*) is applied to this reaction. The phenomena of dissociation are constantly observed throughout the entire range of technical and scientific operations. Even marsh-gas, by a sufficiently high temperature, is resolved into hydrogen and the carbon of the gas retorts; the coal is resolved by dissociation, at a red heat, mainly into marsh-gas, coal-tar, and coke; at a less elevated temperature into those hydrocarbons homologous with marsh-gas, ranging through all of the paraffine series from marsh-gas to solid paraffine wax, leaving a residue of coke. At the temperature required for this last operation a small percentage of another series of hydrocarbons homologous with ethylene appears, but none of the benzole series that characterize coal-tar. "It has been observed that the schistoils of Buxière-la-grue and of Cordesn do not contain benzole and naphthaline, because the distiller purposely works at too low a temperature". (*b*)

Antisell, in *Photogenic Oils*, page 45, says:

The tendency of destructive distillation is to produce compounds possessing more simplicity of composition than the original substance, and capable of sustaining the higher temperatures at which they form unaltered; so that, under the range of temperature indicated (300° to 2732° F.), liquids will be formed when the temperature is least, as at the commencement, and gases when the heat has arisen to the high point set down; and as in the lower ranges, where liquids are produced, the effect of this augmented heat within this lower range is to lessen the complexity of the compound by dropping or reducing its amount of carbon or of hydrogen, it is at the very lowest temperatures that the liquids containing the highest number of atoms of carbon and hydrogen will be found; and when the temperature arises to that essential to the formation of gas, this gas (a carbide of hydrogen) is produced at the expense of the complex liquids formed at first, which give off some carbide of hydrogen, and thus have their proportions simplified.

If then, as has been assumed in these pages, petroleum is the product of the destructive distillation of pyroschists at the lowest temperature possible, it naturally follows that the paraffine series, from marsh-gas up to solid paraffine, would form the bulk of the educts of petroleum. This opinion is confirmed by all that is known either by technologists or chemists concerning the proximate principles that are the *normal constituents of the Paleozoic petroleums found on the western slope of the Alleghanies;* and it is doubtless to this fact that they owe in large part their great superiority over the petroleums of other localities, because the paraffine series of compounds contain the largest proportion of hydrogen as compared with the carbon of any series known to chemists.

Now, when these compounds of the paraffine group are subjected to temperatures above their boiling points, they are dissociated, and the researches of Thorpe and Young upon the distillates of paraffine wax under pressure have shown that they are not decomposed into the lower members of the same series, but into the olefine series, the proportion of the paraffine series being comparatively small. The significance of this discovery lies in the fact that the olefines contain less hydrogen in proportion to the carbon than the paraffine group, and in combustion produce a less brilliant and luminous flame; hence it is to be inferred that while "cracking" will convert a large percentage of petroleum into illuminating oil, the oil will be inferior in quality just in proportion as it consists of cracked oils. The statement that has been made that the present process of manufacture "takes the heart out of the petroleum" for high test-oils and leaves an inferior residue for the ordinary 110° oil is not without some foundation in fact; but it is not true as a general statement, for the amount of material existing in ordinary petroleum suitable for the production of high test-oil is estimated at 10 per cent., while the whole amount of illuminating oil is about 70 per cent. Manifestly, then, the manipulation of the petroleum is a matter of great importance to the consumer of these oils. The manufacturers of reduced petroleum and of high test-oils prepare a strictly paraffine oil from the educts of the petroleum, and convert the remainder either into an 110° oil by "cracking" or into paraffine oils and wax by careful fractional condensation. The 110° oil produced by cracking alone would be much inferior to the same grade of oil produced in an establishment where the bulk of the petroleum was converted into an oil that consists of both educts and products of the distillation.

Illuminating oils are classed and sold as "Water White", "Standard," and "Prime", according to their color. The oils belonging to the paraffine series are neutral, inert oils, not readily acted upon by chemical reagents, and not readily forming substitution compounds. Sulphuric acid removes from such oils the small percentage of unstable oils which they contain and leaves them colorless and limpid or "Water White". With the standard and prime oils, consisting largely of "cracked" oils, the case is wholly different, as they contain members of the olefine group which form substitution compounds with sulphuric acid with great readiness. These compounds are not readily destroyed by solutions of caustic alkali, and therefore remain in the oil. These oils blacken when heated to 200° F., and discharge sulphurous acid (SO_2). When burned, they cause the wick to coat and discharge

a *Am. Chem.*, vii, 81. *b* *Chemical News*, xxviii, 22.

sulphurous acid with the products of combustion. This is abundantly demonstrated by the researches of the German chemist, J. Biel, (*a*) in which he compared oils manufactured from Russian and American petroleum with results shown in the following table:

Varities examined.	Specific gravity at 16° C.	Tension of vapor at 35° C.	Flashing point.	Inflaming point.	Essence or naphtha.	Burning oil.	Heavy oil.	THE COMPARATIVE ILLUMINATING POWER AT—			
								6cm.	9cm.	12cm.	14cm.
		Millimeters.	*Deg. C.*	*Deg. C.*	*Per cent.*	*Per cent.*	*Per cent.*				
Standard	0.795	160	26	39	14.40	45.90	39.7	7	3.35	1.36	0.80
Astral	0.783	5	48	51	2.20	87.80	10.0	7	4.50	3.00	1.36
Imperial	0.789	13	44	46	5.50	80.00	14.0	7	6.00	3.00	1.36
Russian O	0.803	201	26	29	33.50	66.50	....	7	6.25	4.45	3.70
Russian A	0.817	73	28	30	15.40	73.20	10.5	7	5.20	4.00	3.00
Russian B	0.822	45	30	35	12.80	78.30	8.4	7	5.70	3.20	1.65
Russian C	0.821	95	25	26	15.25	71.25	13.5	7	....	....	....

I presume the Imperial oil is an oil manufactured in Germany from crude American petroleum. A comparison of these results shows the great superiority of the Astral and Imperial oils over the Standard. (*b*)

Because these oils, cracked by one distillation and necessarily imperfectly cracked and finished by treatment, are of inferior quality, it is not, however, to be concluded that cracked oils cannot be made of superior grade. The earliest practical application of destructive distillation to the manufacture of illuminating oil was made by the late Luther Atwood, of Boston, Massachusetts. He patented the product and apparatus for obtaining it in 1859, and the process was placed in operation by Mr. Joshua Merrill, of the Downer Kerosene Oil Company, before petroleum became an article of commerce. Mr. Merrill treated thousands of barrels of heavy oil, purchased from those who could not work them often at as low a price as 10 cents a gallon, and cracked them into burning oil of 45°, which, at that time, was readily sold at from 90 cents to $1 40 per gallon. The Downer company have worked this process ever since and have made more or less cracked oil, but they work at low temperatures with steam, and have never made their burning oil with one distillation. Their oils are highly finished products, and the very high reputation that they have always borne is a sufficient guarantee of their excellence. There is really upon the market a great variety of illuminating oils prepared from petroleum, some of which at double the price are cheaper than others, without regard to either their appearance or their safety.

An experiment was made in Boston some years since, which, while without results of practical value, confirmed the views stated above. It was assumed that by cracking naphtha permanent gases would be obtained, and the attempt was made to convert the naphtha into a mixture of marsh-gas and hydrogen by injecting steam into a vessel filled with the volatile liquid. The result was so far successful as to produce a considerable amount of permanent gases, and on evaporating the naphtha remaining a residue of heavy lubricating oil was obtained. (*c*)

Paraffine oil has been frequently converted into illuminating gas by allowing it to drip upon red-hot coke and by other similar processes. An analysis of such a gas in one instance showed it to consist of—

	Per cent.
CH_4, marsh-gas	54.92
C_2H_4, ethylene	28.91
H, hydrogen	5.65
CO, carbonic oxide	8.94
CO_2, carbonic acid	0.82

The presence of ethylene in such large proportion with free hydrogen indicates that at a lower temperature the homologues of that gas would probably be found in still larger proportion. (*d*)

SECTION 2.—"TREATMENT."

Next to the distillation of oils no question is of more importance than the chemical treatment which the distillates receive. It has always been claimed by the Downer company that the proper treatment for illuminating oil is washing with oil of vitriol, to which is sometimes added bichromate of potash, from which the sulphuric acid sets free chromic acid, and then washing with solution of caustic soda, and, finally, distillation over caustic soda. This treatment at one time produced oils that were unrivaled in the markets of the United States, and they have always held a very high reputation. It is, however, claimed by manufacturers of equally high

a Dingler, ccxxxii, 354; Indus. Z., 1879, p. 204; Chem. Z., 1879, p. 285.

b This is a general trade-mark, and not the exclusive property of the Standard Oil Company.

c S. Dana Hayes, A. J. S. (3), ii, 184. I accept the conclusions reached by Mr. Hayes; but the experiment was not conducted so as to exclude the possibility that the heavy oils were dissolved in small quantity in the several thousand gallons of crude naphtha used.

d Archiv der Pharmacie, June, 1874; Am. Chem., v, 431.

reputation that the finishing of oils by distillation is wholly unnecessary, if not positively detrimental. Judging from all that I can learn in reference to this subject, I conclude that the treatment that distillates should receive depends upon what they are. There are:

1. Distillates produced by reducing petroleum.
2. Distillates taken off before cracking commences.
3. Distillates that are wholly cracked.
4. Distillates that are mixtures of 2 and 3.

The first and second classes would consist almost wholly of the paraffine series (C_nH_{2n+2}) of hydrocarbons; that is, inert and neutral to chemicals. Consequently they would be easily treated, and would yield colorless and neutral oils, especially when more or less caustic ammonia is used along with or after the soda treatment. Classes three and four, however, are quite different. These consist of more or less of the olefines (C_nH_{2n}) that are not chemically inert, but form substitution compounds with readiness with such an active reagent as oil of vitriol. In these substitution compounds SO_2 takes the place of two atoms of hydrogen in the hydrocarbon, and the hydrogen unites with the atom of oxygen to form water. It is claimed by those who finish oil by distillation that these substitution compounds are not destroyed by agitation with caustic alkali. Others admit that they are not destroyed by caustic soda, but claim that they are removed by caustic ammonia. I am inclined to think that neither of the caustic alkalies will remove them. I have examined a large number of illuminating oils during the last twenty years, and I have found that a large proportion of them blacken on being heated to 200° F. and yield sulphurous acid fumes. I have never attempted to estimate this quantitatively, but the amount yielded by half a pint has in several instances been such as to be very apparent in the atmosphere about the apparatus. Such oils have not been properly treated. Half a pint is no unusual amount to consume on a winter's evening, and while in the experiments to which I have referred the sulphurous acid was disengaged suddenly and almost instantaneously, the fact that when the oil was burned it would be thrown off slowly would not lessen its quantity nor its effect upon those exposed to its influence. My own conviction is that all oils that will blacken and give off sulphurous acid should be finished by distillation over caustic soda.

The following abstract of an elaborate research undertaken by royal command, and published in Dingler's *Polytechnic Journal* and many other German scientific periodicals, has not before been translated so far as I have learned. Its importance demands for it a wider circulation. The author, H. Vohl, appears to use the term "Roh-petroleum" to designate American refined oils imported into Germany. He asks "if by the burning of petroleum there is not danger of producing unhealthful gases, and whether crude (Roh) petroleum does not itself contain injurious compounds which are kindled by its burning that are removed when it is purified?" and then continues:

The only element of crude petroleum which liberates unwholesome gases when it is burned is sulphur. No petroleum is free from it. In many cases the petroleum is polluted, in the so-called "cold treatment" with sulphuric acid, by sulphur compounds. It is particularly so when an appreciable quantity of paraffine is left in lamp oil, and because of its dark color is subjected to an additional treatment of sulphuric acid. In this way refined oil often contains or retains so much sulphuric acid that its burning develops unwholesome influences. Sulphuric acid in part forms a compound with the heavy paraffine oil which is soluble in the remaining oil, and neither through treatment by water nor by alkalies is it decomposed, so that a subsequent treatment with these substances offers no guarantee for the absence of sulphur. When oil so treated is subjected to distillation, first a clear burning oil passes over, then a rapid development of sulphurous acid gas, often accompanied with coloration of the contents of the retort. Finally, after a limited separation of sulphur has taken place in the neck of the retort, sulphureted hydrogen comes over, and a carbonaceous mass with acid reaction remains. An erroneous opinion is held in many places that a strong blue reflection possessed by many kinds of petroleum is an indication of its superior quality and usefulness Petroleum has this peculiarity when it contains an appreciable quantity of paraffine oil. Most hydrocarbons resembling retinols have these blue reflections, with a high melting point. None of the different kinds of petroleum investigated were free from sulphur or sulphuric acid, and therefore it can be assumed with justice that petroleum burning-oil free from sulphur belongs to the exceptions.

Petroleum, wherever a tranquil light is necessary, has superseded illuminating gas; besides, it is cheaper than coal-gas, so that it is entirely out of the question that the consumption of petroleum should decrease to any important extent, and therefore so much the more necessary in order to direct attention to these sulphur contents, that the removal of the injurious contents must be provided for. Among those who make use of petroleum for illuminating purposes inflammation of the eyes and catarrhal troubles often appear, for which physicians can never afford relief, because the source of the trouble is unknown to them.

The series of experiments embraced the following determinations, beside the sulphuric acid:

(*a*) The specific gravity of the oil at 15° R. water =1.000.

(*b*) The temperature (R.) at which the oil gives off inflammable vapors.

(*c*) The contents in oils of specific gravity 0.740.

(*d*) The contents in paraffine oils of specific gravity, 0.850, solidifying at + 15° R.

(*e*) The consumption of the oil, in grams, per hour in a lamp with a plain burner, with a wick 18^{mm} broad and 2^{mm} thick, having a capillary attraction of 8^{cm}.

In order to determine whether the sulphur is contained as sulphuric acid or as a substitution compound of sulphuric acid with an hydrocarbon, he heated the oil a long time at the boiling point in a glass retort with a piece of sodium or potassium. The bright surface of the alkaline metal is soon covered by a yellowish layer, so that one can safely conclude upon a sulphureted compound in the oil. After cooling add distilled water drop by drop until the excess of alkaline metal becomes oxidized and the sulphur, as sulphide of potassium, passes into solution. Then stir the fluid with a glass rod that has been immersed in a solution of nitro-prusside of sodium. The presence of the smallest quantity of sulphur will immediately color the solution a beautiful violet-blue. (*a*)

a Dingler, ccxvi, 47; W. B., xxi, 1053.

TABULAR STATEMENT OF EXAMINATION OF OILS BY H. VOHL.

No.	Specific gravity.	Temperature at which inflammable vapors are given off.	Per cent. contained in oils of specific gravity 0.740.	Per cent. contained in oils of specific gravity 0.850.	Hourly consumption of oil in grams.	Per cent. of sulphuric acid contained.
		Deg. R.				
1	0.780	23.0	24.964	14.195	16.78	0.994
2	0.790	28.0	18.330	19.519	15.46	2.001
3	0.790	28.0	3.050	5.022	15.00	1.884
4	0.780	27.0	19.889	14.987	16.50	0.946
5	0.805	24.0	22.133	28.666	17.11	1.560
6	0.790	23.0	25.950	9.669	17.20	0.876
7	0.800	27.0	25.345	11.500	14.88	0.998
8	0.790	22.0	35.460	11.590	17.90	1.014
9	0.795	23.5	25.203	12.100	17.12	0.914
10	0.795	27.0	15.233	5.410	14.50	0.348
11	0.800	24.0	25.575	35.769	16.00	3.114
12	0.790	19.0	32.440	19.711	16.14	1.440
13	0.790	19.5	29.580	28.711	17.25	2.100
14	0.790	19.0	33.216	26.461	16.89	1.210
15	0.785	18.0	34.706	3.506	17.98	0.346
16	0.779	8.0	48.051	20.512	19.38	1.950
17	0.790	19.0	38.193	23.367	18.25	2.146
18	0.800	27.5	20.950	32.550	16.50	2.200
19	0.798	25.5	20.600	26.480	17.33	0.216
20	0.795	23.0	21.400	27.140	17.50	0.220
21	0.790	23.0	25.400	35.440	14.20	0.389
22	0.795	24.0	24.116	36.880	14.29	0.401
23	0.790	22.0	36.118	13.400	17.55	0.991
24	0.790	19.0	35.661	14.014	17.24	0.973
25	0.800	27.0	16.033	6.880	15.36	0.310
26	0.795	26.0	18.000	8.446	16.02	0.300
27	0.795	26.0	17.880	9.001	15.98	0.310
28	0.780	9.0	48.336	20.330	19.66	1.977

The amount of sulphur indicated by this table is surprisingly large, but I think it should have been computed as sulphur rather than as sulphuric acid. As sulphuric acid it is already oxidized and would not decompose at 200° F. and appear as sulphurous acid. It is compounds that will burn into sulphurous acid gas, and not sulphuric acid, that render these oils noxious. No examination that I have ever made has led me to think sulphuric acid (SO_3) is present in illuminating oil.

Section 3.—"SLUDGE."

"Sludge" is the name applied to the refuse acid and alkali solutions from the agitators. When petroleum first began to be extensively manufactured, many attempts were made to recover both the acid and the alkali from these spent solutions. The acid forms a black, tarry mass, and the alkali a sort of soapy curd, that forms flocks of a rusty color, and also compounds that pass into solution, as well as sulphate of soda. By evaporating the soda sludge to dryness and calcining to burn out the organic matter an impure carbonate of soda is obtained that can be converted into caustic soda by the ordinary process. The sulphate of soda and other impurities thus accumulate in the soda solution and finally render its action imperfect. As this simple process for recovering the soda has never been used to any considerable extent, I infer that it has never, on the whole, been considered profitable. There was used during the census year an amount of soda crystals, soda-ash, and caustic soda estimated to be equivalent to 3,500 tons of soda-ash, all of which ran to waste.

The sludge acid is recovered by first heating it, when it separates into an oily superficial layer and a heavy layer beneath containing the acid. This acid liquid is drawn off and evaporated and concentrated like chamber acid, the black carbonaceous matter being destroyed at the high temperature required for concentration. This process is also very simple, but it produces abundant suffocating fumes and disagreeable odors, and in the neighborhood of dense populations is justly considered a great nuisance. At Cleveland, Ohio, and near Titusville, Pennsylvania, there are establishments for recovering spent acid, to which the acid sludge is carried in tank-cars. The manufacturers of petroleum are paid an amount sufficient to induce them to put their sludge into tank-cars rather than to allow it to run to waste, and the recovered acid is returned to them at the ruling price for sulphuric acid. Sludge acid is sold to the manufacturers of commercial fertilizers in localities where the refineries are convenient to such establishments. Much, however, is allowed to run to waste; it is run into rivers and lakes, and, in the neighborhood of New York, is conveyed in barges outside of New York harbor and emptied into the sea. The amount of this material that has been thrown into Oil creek and the Allegheny river is enormous. It has lodged upon the rocks and on the gravel along the creek and stained them black; and it floats upon the river continually,

often communicating its peculiar odor to the atmosphere above. I have also noticed it from the deck of a Sound steamer floating on the East river, its peculiar odor being perceptible at the level of the deck nearly all of the distance from Blackwell's island to the Battery. During the census year 45,819.5 tons of sulphuric acid were used in the manufacture of petroleum products. Of this vast quantity 21,158.75 tons were recovered, 22,162.5 tons were sold to manufacturers of fertilizers, and 2,498$\frac{1}{6}$ tons were "run to waste", which phrase means discharged into lake Erie, the tributaries of the Ohio river, the Delaware river, Chespeake bay, or the ocean.

The effect of both acid and alkaline sludge upon fish was investigated by Dr. Stevenson Macadam, and the results were communicated in 1866 to the British Association for the Advancement of Science. He made dilute solutions of different strengths and immersed fish in them with the following results:

1, a fish placed in the acid sludge died in five minutes; 2, in one part sludge and three of water, it died in ten minutes; 3, in one part sludge and twenty of water, it died in fifteen minutes; 4, in one part sludge and one hundred of water, it died in fifteen minutes; 5, in one part sludge and one thousand of water, it died in two hours; while in one part sludge to ten thousand parts of water the fish were not killed for twenty-four hours, but were apparently sick and prostrate. The spent-soda liquor which has been employed in treating oil which has been previously acted upon by acid is decidedly alkaline and caustic in its nature. It has extracted from the oil and holds in solution more or less carbolic acid and its homologues, and the poisonous nature of the spent-soda liquor is doubtless augmented by the presence of these acids. A sample of this soda liquor which was flowing from a paraffine oil manufactory, and which contained extra water, proved destructive to fish in ten minutes; with three parts of water it killed fish in twenty minutes; with twenty parts of water, the fish were dead in twenty-five minutes; with one hundred parts of water, the fish were dead in thirty minutes; diluted with one thousand times its volume of water, the soda liquor proved destructive to fish in twenty hours; while with ten thousand parts of water the fish were not killed, but were apparently slightly sick. (*a*)

He also found that shale oil, Pennsylvania petroleum, and their manufactured products, were all deleterious to fish; but the shale oil was more injurious than petroleum.

If these sludge solutions were mixed, and as a result sulphate of soda instead of free sulphuric acid and caustic soda were discharged into the streams, the injurious effects upon animal life would without doubt be lessened; but even in that case the discharge of such vast quantities of mineral and organic poisons into streams the waters of which are used by thousands of the inhabitants of the towns upon their banks cannot be viewed as anything less than a public misfortune, if no regard whatever is had to the fish with which the streams are stocked. The extent of such injury as a problem in public health, as compared with other interests, is properly a subject of inquiry for the physician.

SECTION 4.—FIRES.

The attention of the public was called to the great danger of allowing large quantities of either crude or refined oil to be stored within the limits of large cities by the disastrous fires that occurred in Philadelphia in March, 1865. A quantity of oil, amounting to what would now be considered only a few thousand barrels, was stored in some open sheds on a lot that was not otherwise occupied. This oil was set on fire, as was supposed by an incendiary, very early on a cold morning early in March. The flames spread rapidly, and as the barrels burst the contents accumulated in a pool of burning oil that soon overflowed the lot, and, filling the frozen gutters, ran down a narrow street in the neighborhood in a rivulet of flame as high as two-story houses. Houses were set on fire, and their occupants, fleeing for life, were overtaken by the stream of fire and burned before they could escape. In this way several lives were lost. This catastrophe led to the enactment of laws forbidding the storage of petroleum within the limits of large cities, and in the case of Philadelphia the railroad carried a branch track to tide-water below the city for its delivery and shipment.

Petroleum refineries have been considered especially liable to destruction by fire, yet some of the oldest establishments in the country have received very little injury from that source. The amount of capital invested in the manufacture of petroleum during the census year was $27,325,746. Of this, $21,196,246 was used twelve months, $318,000 eleven months, $2,315,000 ten months, $2,019,000 nine months, $727,000 eight months, $100,000 seven months, $510,000 six months, $100,000 five months, $36,000 four months, and $4,500 three months, equal to $25,781,327 used for twelve months. During the same time the losses from fire in the refineries of the country amounted to $104,631, or less than one-half of 1 per cent. When to this invested capital is added the total value of manufactured products that passed through these establishments, equal to $43,705,218, the total being $71,100,964, these losses are insignificant. The refineries lately constructed are for the most part uncovered, and the material about them that can burn is reduced to a minimum; but the older refineries that have not burned are inclosed in very substantial buildings, provided with ample means for completely filling them with steam in case of any accidental ignition of the oil. Really the danger from fire depends upon the want of care exercised by those who have charge of the refineries more than upon any especial appliances for preventing or extinguishing them. The great fire in Titusville in June, 1880, and caused by lightning. Against the occasional destruction of property by the elements no amount of foresight or precaution will prevail.

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a *Chemical News*, xiv, 110.

SECTION 5.—THE SPECIAL TECHNOLOGY OF CALIFORNIA PETROLEUM.

The earliest attempts to manufacture the petroleum of southern California were made by Mr. Gilbert, of San Buenaventura, about 1860, who distilled the malthas of the Ojai ranch and obtained from them a small quantity of oil of inferior quality that could be used for illumination. When I commenced my experiments in 1865 upon the same material I was soon convinced that it was quite different from the petroleum with which I was familiar on the Atlantic coast. The yield of oil of a specific gravity suitable for illuminating purposes was small in quantity, and burned in the lamps in use for Pennsylvania oils with a dull and smoky flame. The proportion of oil of medium specific gravity was very large, and the heavy oils, while of very low specific gravity, were not unctuous, and were destitute of lubricating properties. One of these denser distillates, with a specific gravity of 16° B., was a mobile fluid-like water or an essential oil. When the Hayward Petroleum Company and Stanford Brothers commenced the manufacture of petroleum from their springs and tunnels in San Francisco they encountered the same difficulties on a large scale. The oils were all of inferior quality, and the "middlings", as they were called, were so large a proportion of the distillate as to prove a very great obstacle to the success of the enterprise.

Professor Silliman secured a barrel of the Ojai malthas and carried it to Boston, where he worked it in the experimental apparatus of the Downer company. From the report of his results I make the following abstract:

The crude oil is very dark. At ordinary temperatures (60° F.) it is a thick, viscid liquid, resembling coal-tar, but with only a very slight odor, and with a density of 0.980 or 13½° B. It retains, mechanically entangled, a considerable quantity of water. The tar froths at the commencement of distillation from the escape of watery vapor. It yields by a primary distillation no product having a less density than 0.844, or 37° B. at 52° F. Distillation to dryness gave:

	Per cent.
Of oil having a density of 0.890 to 0.900	69.82
Coke, water, and loss	30.18
	100.00

This first distillate, having a density of about 0.890 at 60° F., gave, when subjected to slow distillation, a product having a density of 0.885, which, after treatment with oil of vitriol and soda lye and redistillation from soda, had a density of 0.880. This distillate was then fractionated, and yielded:

	Per cent.
Light oil of specific gravity 0.835 at 60° F	21.58
Heavy oil of specific gravity 0.880 at 66° F	37.41
Heavy oil of specific gravity 0.916 at 64° F	34.53
Coke	6.48
	100.00

In another experiment, undertaken with a view to "cracking", treating, and redistilling with soda, the products were expressed in percentages of the whole amount operated upon as follows:

	Per cent.
Naphtha of specific gravity 0.760 at 60° F	11.33
Oil of specific gravity 0.836 at 60° F	66.22
Oil of specific gravity 0.893 at 60° F	12.67
Oil of specific gravity 0.921 at 60° F	3.56
Loss	6.22
	100.00

Further experiments by distillation under pressure gave:

	Per cent.
Light oil, specific gravity 0.825 at 60° F	19.20
Heavy oil, specific gravity 0.885 at 60° F	25.86
Heavy oil, specific gravity 0.918 at 60° F	38.14
Coke and loss	16.80
	100.00

No paraffine could be detected by refrigerating any of these heavy oils in salt and ice. (*a*)

On returning from California to New England, in 1866, I brought with me a few gallons of several of the petroleums and malthas of the neighborhood of San Buenaventura. It was my intention to treat these samples in an apparatus similar to that used by Mr. Merrill, but the small quantity of each specimen at my disposal rendered that operation very difficult, and I subsequently determined to distill them under pressure, after the manner patented by Young. I contrived a small retort, with a valve of peculiar construction, described in the *American Journal of Science* for September, 1867. (*b*) These specimens of petroleum, numbered I, II, and III, were subjected to this treatment. No. I came from a tunnel in the Sulphur mountain (see Fig. 6), with a specific gravity 0.9023; No. II, from the Pico spring, with a specific gravity 0.8932; and No. III, from the Cañada Laga spring, with a specific gravity 0.9184. They were first subjected to distillation under a pressure of about 30 pounds per square inch in a

a A. J. S., xliii, 242; C. N., xvii, 257; B. S. C. P., 1868, 77. *b* A. J. S. (2), xliv, 230; C. N., xvi, 199; W. B., 1867, 725

measured quantity of 1,500 c.c. The distillate obtained was then fractionated until the specific gravity of the distillate averaged 0.810 or 43° B. The heavy residue in the retort was again distilled under pressure and fractionated to a distillate of specific gravity 0.810. The heavy residue in the retort was then treated for lubricating oil. The results tabulated as follows:

1,500 c. c. of crude oil for each experiment.	First pressure distillation.	Coke and loss at distillation.	First fractionation of sp. gr. 43° B.	Heavy residue for re-distillation.	Yielding by second pressure distillation.	Second fractionation of sp. gr. 43° B.	Total crude illuminating oil.	Three per cent. loss in treating illuminating oil.	Total yield of refined oil.	Total crude lubricating oil.	Three per cent. loss in treating lubricating oil.	Total refined lubricating oil.	Yield of refined illuminating oil.	Yield of refined lubricating oil.	Loss in refining.	Loss in distillation.
Cubic centimeters:																
I	1,365	135	630.00	735.00	681.00	184.00	814.00	24.42	789.58	497.00	14.91	482.09	789.58	482.09	39.33	189.00
II	1,315	185	850.80	464.20	408.78	102.19	952.99	28.59	924.40	306.59	9.19	297.40	924.40	297.40	37.78	240.42
III	1,240	260	605.00	635.00	571.50	142.87	747.87	22.43	725.44	428.63	12.85	415.78	725.44	415.78	35.28	323.50
Percentages:																
I	91.00	9.00	42.00	49.00	45.40	12.27	54.27	1.63	52.64	33.13	0.99	32.14	52.64	32.14	2.62	12.60
II	87.66	12.34	56.72	30.94	27.25	6.81	63.53	1.91	61.62	20.44	0.61	19.83	61.62	19.83	2.52	16.03
III	82.66	17.34	40.33	42.33	38.10	9.52	49.85	1.49	48.36	28.58	0.86	27.72	48.36	27.72	2.35	21.57
Cubic centimeters:																
IV	1080.00	232.50	250.00	830.00	747.00	186.75	436.75	13.10	423.65	560.25	16.80	543.45	423.65	543.45	29.90	503.00
Percentages:																
IV	72.00	15.50	16.70	55.30	49.80	12.40	29.10	0.90	28.20	37.40	1.10	36.30	28.20	36.30	2.00	33.50

The specimen of maltha (IV) examined was taken, it is supposed, from the same pool on the Ojai ranch as that examined by Professor Silliman. Its specific gravity was 0.9906. The air, hydrogen sulphide, and water was removed by allowing the maltha to flow slowly from one vessel through a second vessel, in which it was heated sufficiently to expel these impurities, and from which it flowed into a receiver. The loss by this treatment was 12½ per cent. The purified maltha was then treated precisely like the oils, with the results as given above.

As these results, both with malthas and oils, were conducted on a small scale, the percentage of loss is much greater than would be experienced on a commercial scale.

A comparison of the results of the distillation of the malthas and oils appear at first sight to give the latter great preponderance in value over the former; but it should be borne in mind that the malthas contain 12½ per cent. of volatile impurity not contained in the oils. After making due allowance for this fact, it will be observed that the total amount of crude distillate is in all cases very nearly in the same proportion to the pure bitumen contained in the crude materials. These crude distillates yield easily to treatment with the ordinary amount of sulphuric acid and soda lye. The purified oil is very transparent and the most free from color of any that I have seen. Indeed, were it not for its opalescent properties, and the peculiar manner in which light is refracted by it, this oil could not be distinguished by the eye from pure water. I do not claim to have produced oils the burning qualities of which are superior to other California oils, but I think them in no way inferior to the best that have been produced from unadulterated California petroleum. The best refined California petroleum that I have made, as also the best that I have seen from other sources, fails to produce a light of such intense whiteness as the best refined Pennsylvania oils, although they are quite equal to the average upon the market. It is my opinion that this difference is due to admixture of some series of hydrocarbons, *containing a large amount of carbon in proportion to the hydrogen, in such quantity as to render the combustion incomplete, and thus give rise to a yellow flame.* (*a*)

An examination of Russian petroleum in 1881 by Kurbatow and Beilstein has shown the presence of an homologous series such as was here predicted, which contains more hydrogen than the benzole series and less hydrogen than the paraffine series. There is a great similarity between these Tertiary Russian petroleums and the California petroleums of the same geological age, and it is altogether probable that they both contain these "additive compounds of the benzole series". I am informed that during the last ten years or more there have been a number of thousands of barrels of petroleum refined in Santa Barbara and Ventura counties which has been sent into Arizona and Mexico, but was not of such a quality as to compete in the San Francisco market with oils manufactured on the Atlantic coast. On the whole, so far as I can learn, the oils manufactured from crude California petroleum are uniformly of inferior quality.

a S. F. Peckham, *Geo. Surv. of California:* Geology II, Appendix, page 73.

CHAPTER VI.—STATISTICS OF THE MANUFACTURE OF PETROLEUM DURING THE CENSUS YEAR.

SECTION I.—INTRODUCTION.

The statistics that form the subject of this chapter were obtained by means of a schedule of questions which were placed in the hands of the different manufacturers, and the answers have been consolidated into the totals as here given. Great care has been taken to include all parties engaged in the manufacture during the whole or any part of the census year, and it is believed that the list is complete. It is further believed that the schedules have been filled with as much care and regard to accuracy as could be expected under the circumstances. Several firms had gone out of the business at the time the statistics were compiled, and others had kept their books in such a manner as to render the compilation of such statistics difficult. It is believed, however, that in those instances where absolute accuracy was found to be impossible approximately correct estimates have been given. These instances constituted but a small percentage of the bulk of the business, which is carried on by large corporations and firms, who conduct their business systematically. The statistics furnished by these concerns have been compiled at much labor and expense, and in many instances are careful transcripts of annual or biennial balances and records kept in the regular course of conducting the business. As statistics of this character constitute a large proportion of the whole number, and as the remainder are carefully computed and estimated, the totals are believed to represent in a practically accurate manner the details of the business of the country for the census year.

The following-named firms and corporations have furnished statistics:

Name.	Location.
Portland Kerosene Oil Company	Portland, Maine.
Downer Kerosene Oil Company	Boston, Massachusetts, and Corry, Pennsylvania.
Oriental Oil Company	Do.
Maverick Oil Company	Do.
Pierce & Canterbury	Do.
S. Jenney & Sons	Boston, Massachusetts, and Brooklyn, New York.
G. F. Gregory	Do.
Charles Pratt & Co	Do.
Empire Refining Company	Do.
Sone & Flemming	Do.
James Donald & Co	Do.
Wilson & Anderson	Do.
Bush & Denslow	Do.
Franklin Oil Works	Do.
Devoe Manufacturing Company	Do.
McGoey & King	Do.
Queens County Oil Refining Company	Do.
James A. Bostwick	Brooklyn, New York.
Long Island Oil Works	Do.
Lombard, Ayres & Co	New York city.
Cheesboro' Manufacturing Company	Do.
Leonard & Ellis	Do.
A. C. Bunce & Co	Do.
Hudson River Oil Works	Bergen county, New Jersey.
Bayonne Refining Company	Bayonne, New Jersey.
Pennsylvania Refining Company	Philadelphia, Pennsylvania.
Malcom, Loyd & Co	Do.
William L. Elkins & Co	Do.
Harkness Refining Company	Do.
Webster Bros. & Wilson	Do.
Atlantic Refining Company	Do.
Excelsior Oil Company	Do.
United Oil Company	Baltimore, Maryland.
J. Parkhurst, jr., & Co	Do.
Camden Consolidated Oil Company	Baltimore, Maryland, and Parkersburg, West Virginia.
Solar Oil Company	Williamsport, Pennsylvania.
S. Bailey & Co	Danville, Pennsylvania.
Reading Oil Company	Reading, Pennsylvania.
Binghamton Oil Company	Binghamton, New York.
Vacuum Oil Company	Rochester, New York.
Buffalo Oil Works	Buffalo, New York.
Standard Oil Company	Cleveland, Ohio.
Pioneer Oil Company	Cleveland, Ohio.
Merriam & Morgan	Do.
L. D. Mix	Do.
American Lubricating Oil Company	Do.
Republic Refining Company	Do.
Backus Oil Company	Do.
William H. Doan	Do.
Schofield, Schurmer & Teagle	Do.
Forest City Varnish, Oil, and Naphtha Co	Do.
J. H. Heisel & Co	Do.
J. R. Timmins & Co	Do.
Acme Oil Company	Titusville, Pennsylvania.
Keystone Oil Company	Do.
White Star Oil Company	Do.
Crystal Oil Works	Miller's farm, Pennsylvania.
Imperial Refining Company	Oil City, Pennsylvania.
Mutual Refining Company	Reno, Pennsylvania.
Empire Oil Works	Do.
Eclipse Oil Company	Franklin, Pennsylvania.
Relief Oil Works	Do.
Franklin Oil Works	Do.
German Refining Company	Brady's Bend, Pennsylvania.
William Bradin	Millerstown, Pennsylvania.
Holdship & Irwine	Pittsburgh, Pennsylvania.
Standard Oil Company	Do.
Paine, Ablett & Co	Do.
E. J. Waring	Do.
A. D. Miller	Do.
J. A. McKee & Sons	Do.
Central Refining Company	Do.
D. P. Reighard	Do.
Andrew Lyons & Co	Do.
Wallover Oil Company	Smith's Ferry, Pennsylvania.
Samuel Hodkinson	Steubenville, Ohio.
Marietta Refining Company	Marietta, Ohio.
Ohio Oil Works	Do.
Argand Oil Company	Do.
Richard Patton	Do.
O. M. Lovell	Do.
Isaiah Warren & Co	Wheeling, West Virginia.
L. D. Crafts	Parkersburg, West Virginia.
Sweetzer Oil Company	Do.
S. P. Wells & Co	Do.
Chess, Carley & Co	Louisville, Kentucky.

SECTION 2.—CAPITAL, LABOR, AND WAGES.

The total amount of capital invested in the manufacture of petroleum during the census year was $27,325,746. Of this amount, $21,196,246 was employed the entire year and $6,129,500 for periods varying from one to eleven months, averaging $4,585,081 for twelve months. The total average amount of capital employed throughout the year was $25,781,327. (See page 183.)

The total number of hands employed was 12,231. The average number was: Men, 9,498; women, 25; children, 346; total, 9,869. Some of these men were employed in establishments that were in operation less than twelve months. The average number of men employed for twelve months was 8,032. Of the 9,498 men, 8,818 were employed by day and 680 by night. This latter number does not represent all of the labor employed at night, as in many establishments the work was not performed by men who worked constantly at night, but by men who were divided into sets and alternated, one set working during the day for one week, and at night the following week. In other establishments the work was divided from twelve at noon to twelve at night.

The wages paid for skilled labor varied from $1 50 to $3 per day, averaging about $2 25, and in general no difference was made in the wages of those who worked by day from those who worked at night. Ordinary laborers were paid from $1 25 to $2 per day, averaging about $1 50; coopers from $1 50 to $2 50, averaging about $2 25, and tinsmiths from $1 30 to $2 25, averaging about $2. The highest wages were paid on the Atlantic coast and the lowest on the Ohio river. The total amount paid in wages during the census year was $4,381,572.

SECTION 3.—MATERIALS EMPLOYED IN MANUFACTURING PETROLEUM.

The total amount of crude petroleum manufactured during the census year was 731,533,127 gallons, equal to 17,417,455 barrels of 42 gallons each. This crude oil was valued at $16,340,581, equal to 92.9 cents per barrel. During the year there was received by the manufacturers in—

	Gallons.
Barrels	20,363,918
Barges	42,433,388
Tank-cars	437,740,951
Pipe-lines	227,941,728

This oil is estimated to contain on an average 1 per cent. of water, and was mainly third-sand oil; but it includes also nearly all of the second-sand oil, and a portion of the first-sand. It does not include any of the heavy oils that are used as natural oil, and but a small portion, if any, of the mixed oils.

In the manufacture of this oil there was consumed the following kinds and amounts of fuel:

			Value.
Anthracite coal	tons	179,997	$446,922
Bituminous coal	tons	504,667	580,983
Wood	cords	1,471	6,355
Coke	bushels	303,596	13,218
Naphtha	gallons	2,892,164	42,315
Residuum	gallons	11,765,705	229,215
Total valuation of fuel used			1,319,008

Anthracite coal was very generally used in the Atlantic cities, but not to the exclusion of bituminous coal. Naphtha and residuum do not appear to have been used as fuel except in special cases. This fuel was used in the distillation of the oil and in the production of steam for use both as power and in distillation.

In the treatment of the distillates there were used of—

			Value.
Sulphur	tons	3	$180
Sulphuric acid	do	45,813½	1,206,052
Hydrochloric acid	pounds	3,424	68
Total value of acids			1,206,200

Of this vast quantity of sulphuric acid the "sludge" of 22,162½ tons was sold to fertilizer and chemical manufacturers, that of 21,158⅞ tons was returned to the manufacturers to be restored, and that of 2,498⅙ tons ran to waste. Of this amount, 1,389 tons of the 2,498⅙ tons that ran to waste were thrown into the Atlantic ocean and rivers and bays that enter it, 839⅝ tons were thrown into the Ohio river and its tributaries, and 269½ tons into lake Erie. The proportion of sulphuric acid that is thrown to waste is now much less than it was formerly, but the nearly 5,000,000 pounds wasted during the census year is a large quantity with which to pollute our rivers and bays. The 1,678,000 pounds thrown into the tributaries of the Ohio river is a large contamination in the waters of even so large a river, and in addition to the acid the sludge oils cannot fail to increase its deleterious effects.

The alkali treatment was effected by means of—

			Value.
Soda-ash	tons	410.9	$10,427
Caustic soda	do	772.3	85,064
Sal-soda	pounds	96,643.0	1,423
Aqua ammonia	do	160,160.0	8,697
Lime	bushels	797.0	159
Total value of alkalies			105,770

The sludge of all of this alkali was run to waste on the Atlantic coast, into the Ohio and its tributaries, and into lake Erie.

The filtered oils and residues required the use of 1,990 tons of bone-black, valued at $62,815. The packages used were in part manufactured and in part purchased by the petroleum refiners, and were as follows:

		Value.
Barrels: Made	3,292,698	$4,040,502
Purchased	6,424,608	7,577,805
Total	9,717,306	11,618,307
Tin cans: Made	23,496,916	2,700,630
Purchased	344,173	93,367
Total	23,841,089	2,793,997
Packing cases: Made	1,607,297	189,511
Purchased	4,845,504	717,400
Total	6,452,801	906,911

The total number of all packages and their value was as follows:

Barrels	9,717,306	$11,618,307
Cans	23,841,089	2,793,997
Cases	6,452,801	906,911
Total packages	40,011,196	15,319,215

Where barrels are not made they are being continually repaired. The number of coopers employed was 2,062, and of tinsmiths, 353.

The following is the total cost of materials:

	Value.
Crude oil, 17,417,455 barrels	$16,340,581
Fuel	1,319,008
Acid	1,206,200
Alkali	105,770
Bone-black	62,815
Packages	15,319,215
Bungs, paint, hoops, glue, etc	645,412
Total	34,999,001

SECTION 4.—THE PRODUCTS OF MANUFACTURE.

There were manufactured of the volatile products of the distillation of petroleum of a specific gravity above 87° Baumé 293,423 gallons, valued at $29,117. This material was first called rhigolene, but a similar product has been called cymogene, and has been used in ice-machines. It is to be presumed that this material was used for that purpose. Of gasoline there was manufactured 289,555 barrels, valued at $1,128,166; of naphthas the following-named qualities and quantities:

Specific gravity.	Quantity in barrels.	Value.
Degrees.		
60	1,200	$3,600
62	109,472	225,609
63	18,945	43,039
65	6,148	17,339
68	7,300	20,075
70	918,374	1,188,201
71	1,617	4,657
71–72	6,899	18,110
72	6,048	3,931
73	38,777	45,945
74	19,565	54,110
75	8,100	34,425
76	11,609	39,315
68–70	12,525	16,282
65–70	260	780
60–72	42,302	109,417
68–78	3,400	8,500
65–76	85	60
Total	1,212,626	1,833,395

An inspection of the table on page 188 shows that the different grades of naphtha, as determined by the specific gravity, command very different prices. The following table shows the fire-test and quantities of illuminating oils manufactured:

Fire-test.	Quantity in barrels.	Value.
Deg. F.		
100	2, 059	$6, 435
110	6, 083, 026	19, 035, 913
112	913, 979	2, 621, 777
115	90, 814	313, 560
120	2, 107, 220	7, 096, 218
110–120	5, 948	16, 844
130	510, 522	1, 507, 884
135	2, 036	11, 233
140	15, 000	85, 000
150	1, 170, 725	5, 494, 833
110–150	28, 270	108, 557
155	1, 960	7, 350
160	1, 627	9, 949
175	22, 843	164, 914
150–175	46, 220	359, 144
Total	11, 002, 249	36, 839, 611

It will be noticed that the three grades of 110°, 120°, and 150° include the larger proportion of the illuminating oils. The specific gravity of these oils varies from 45° to 50° Baumé, the high-test oils having usually the highest specific gravity. But a comparatively small quantity of oils having a fire-test above 200° F. was produced.

Fire-test.	Barrels.	Value.
Deg. F.		
260	1, 940	$8, 245
285	300	3, 000
300	14, 304	191, 480
Total	16, 544	202, 725

These oils are of a specific gravity of 36° to 39° Baumé.

The lubricating oils are prepared by various parties of different specific gravities. Petroleums reduced especially for cylinders are made very dense, and vary from 25° to 28° Baumé. Of these oils there were produced 26,018 barrels, valued at $371,020. Petroleums reduced for journals are prepared in greater variety. Of these there were:

Specific gravity.	Barrels.	Value.
Degrees.		
28	8, 184	$30, 327
28–30	105, 095	506, 957
29	63, 705	300, 203
29–34	26, 657	179, 510
38	1, 200	7, 020
Total	204, 841	1, 024, 017

The distilled lubricating oils are in equally large variety. Of the deodorized lubricating oils there were produced:

Specific gravity.	Barrels.	Value.
Degrees.		
25	16, 460	$148, 140
26	2, 017	9, 580
28	68	340
29	12, 440	149, 280
28–33	39, 430	304, 232
Total	70, 415	611, 572

The paraffine oils reported are in still greater variety of specific gravity and price, ranging from about $2 to nearly $12 per barrel; the latter value being assigned to an exceptionally dense oil of specific gravity 20° Baumé. Of these oils there were produced:

Specific gravity.	Barrels.	Value.
Degrees.		
20	2,524	$24,230
20-27	8,733	33,297
24	552	4,668
25	26,293	165,555
26-28	6,000	45,000
27	3,187	6,055
28	31,462	124,077
33	714	5,141
Total....	79,465	408,023

Of paraffine wax there was produced 7,889,626 pounds, valued at $631,944, an average valuation of about 8 cents per pound, of which 900,000 pounds were made into candles by one firm.

Of residuum there was produced and sold 229,133 barrels, valued at $297,529.

The products of manufacture other than those already enumerated were chiefly petroleum ointment, harness oil, and other vacuum products, as follows:

The paraffine ointment manufactured had a value of more than	$100,000
Harness oil	34,513
Other products	193,584
	328,097

SUMMARY OF PRODUCTS OF THE MANUFACTURE OF PETROLEUM AND THEIR VALUE.

Article.	Barrels.	Value.
Rhigolene	5,868	$29,117
Gasoline	289,555	1,128,166
Naphtha	1,212,626	1,833,395
Illuminating oil	11,002,249	36,839,613
Mineral sperm	16,544	202,725
Reduced petroleum, for cylinders	26,018	371,020
Reduced petroleum, for journals	204,841	1,024,017
Deodorized lubricating oils	70,415	611,572
Paraffine oil	79,465	408,023
Residuum	229,133	297,529
	13,136,714	
Paraffine wax	* 7,889,626	631,944
Miscellaneous products		328,097
Total		43,705,218

* Pounds.

Section 5.—BUILDINGS, MACHINERY, ETC.

There were in use during the census year 374 boilers, of an aggregate capacity of 12,744 horse-power. The machinery was driven by 285 steam-engines, in addition to which there were 200 steam-pumps. These pumps were of very varied capacity and construction. Many of them were small, requiring only a few horse-power to run them, while others were very powerful machines, capable of handling hundreds of barrels of oil per hour. The number of buildings in use were reported at 866, and varied in character from rude sheds to substantial brick buildings, their aggregate value being $1,899,288, while the machinery was valued at $3,737,998. The losses reported as occasioned by fire and other acccidents aggregate $104,631 43, a loss on the capital in use in the business during the year of four-tenths of 1 per cent.

An attempt was made to ascertain the quantities of the different products packed by the manufacturers for export, but a number of the returns contained so many errors that the results were worthless.

SUMMARY OF STATISTICS OF THE MANUFACTURE OF PETROLEUM DURING THE YEAR ENDING MAY 31, 1880.

Capital invested	a $27,325,746
Capital in use for twelve months	$25,779,688
Total number of hands employed	12,231
Average number of men employed	9,498
Average number of women employed	25
Average number of children employed	346
Total average number of hands employed	9,869
Total amount paid in wages	$4,381,572
Value of crude material	$34,999,001
Value of manufactured products	$43,705,218
Boilers in use	374
Horse-power of same	12,744
Engines in use	285
Pumps in use	200
Number of buildings	866
Value of buildings	$1,899,288
Value of machinery	3,737,998
Loss during the census year from fire, etc	104,631

STATISTICS OF PETROLEUM REFINING DURING THE YEAR ENDING MAY 31, 1880.

Establishments:	
Number of firms and corporations	86
Capital:	
Amount of capital invested	$27,325,746
Hands employed:	
Average number of men	9,498
Average number of women	25
Average number of children	346
Total	9,869
Wages:	
Total amount paid	$4,381,572

Materials:

		Quantities.	Value.
Oil.			
Crude oil used (b)	gallons	731,533,127	$16,340,581
Fuel.			
Anthracite coal	tons	179,997	446,922
Bituminous coal	do	504,667	580,983
Wood	cords	1,471	6,355
Coke	bushels	303,596	13,218
Naphtha	gallons	2,892,164	42,315
Residuum	do	11,765,705	229,215
Chemicals.			
Sulphur	tons	3.0	180
Sulphuric acid	do	45,813.5	1,206,052
Hydrochloric acid	pounds	3,424.0	68
Soda-ash	tons	410.9	10,427
Caustic soda	do	772.3	85,064
Sal-soda	pounds	96,643.0	1,423
Aqua ammonia	do	160,160.0	8,697
Lime	bushels	797.0	159
Bone-black	tons	1,990.0	62,815

a This differs from the sum given in the Compendium ($27,395,746), an error of $70,000 having been detected after that was printed.
b The 731,533,127 gallons of crude oil used are equal to 17,417,455 barrels of 42 gallons each.

	Quantities.	Value.
Packages.		
Barrels .... number..	9,717,306	$11,618,307
Tin cans .... do....	23,841,089	2,793,997
Cases .... do....	6,452,801	906,911
Bungs, paint, glue, etc		645,412
Total value of raw material		34,999,101
PRODUCTS:		
Rhigolene .... barrels..	5,868	$29,117
Gasoline .... do....	289,555	1,128,166
Naphtha .... do....	1,212,626	1,833,395
Illuminating oil .... do....	11,002,249	36,839,613
Mineral sperm .... do....	16,544	202,725
Reduced petroleum, for cylinders .... do....	26,018	371,020
Reduced petroleum, for journals .... do....	204,841	1,024,017
Deodorized lubricating oils .... do....	70,415	611,572
Paraffine oil .... do....	79,465	408,023
Residuum .... do....	229,133	297,529
Paraffine wax .... pounds..	7,889,626	631,944
Petroleum ointment, harness oil, etc		328,097
Total value of manufactured products		43,705,218
MISCELLANEOUS STATISTICS:		
Boilers in use		374
Horse-power of same		12,744
Engines in use		385
Pumps in use		200
Number of buildings		866
Value of same		$1,899,288
Value of machinery		3,737,998
Loss during the census year from fire and other accidents		104,631

PART III.

THE USES OF PETROLEUM AND ITS PRODUCTS.

PART III.

Chapter I.—THE USE OF MINERAL OILS FOR LUBRICATION.

Section 1.—INTRODUCTION.

Wagner's *Berichte* for 1879 contains a very full discussion of the subject of lubrication and lubricating oils. It is there remarked:

A mineral oil which, without admixture of another oil or body, as a lubricator is of unquestionable advantage. It must possess the following characteristics: 1st, it must possess the necessary consistence; 2d, it must not harden; 3d, it must not contain any mineral or organic acid (creosote); 4th, it must begin to evaporate and inflame at a high temperature (not less than 150° C.); 5th, it must also, at a low degree of cold, show no separation of paraffine; 6th, it should possess only a faint odor.

He further says:

American lubricating oils are sold under the names of "Lubricating oil", "Eclipse oil," "Globe oil," "Valvoline;" also so-called "Natural lubricating oil", which is natural West Virginia oil reduced in a vacuum, together with complex mixtures and material produced by patent processes from residuum. The lighter and clearer oils are spindle oils, those more heavy are machine oils, and the specifically heaviest in consistence and evaporating point are used for cylinders under the name of cylinder oil. The higher the specific gravity of these oils the less their fluidity and the higher their evaporating point. The specific gravity of the American lubricating oils varies from 0.865 to 0.915 at 15° C. They stiffen according to quality between —6° and —30° C., most of them between —10° and —12° C. With the exception of the West Virginia Globe oils, which are sometimes found to evaporate at 200° C., they inflame between 250° and 360° C., and boil mostly above 360° C. (*a*)

This may be taken as a fair representation of the subject as presented in the United States as well as in Germany. Although there have been those who have advocated the use of mineral lubricators for many years, it is only quite recently that any general admission of their claims to superiority has found expression. The whole question of lubrication is under discussion, and has been made the subject of a large number of memoirs during the last few years. Among these may be mentioned a very full discussion of the subject that appeared in *Le Technologiste* in 1868, two works that appeared in Germany in 1879, one by E. Donath (*b*) and the other by M. Albrecht, (*c*) and a work that was issued the same year by Professor R. H. Thurston, of the Stevens Institute of Technology, at Hoboken, New Jersey, published by Trübner & Co., of London. (*d*)

During the year 1878 the Boston Manufacturers' Mutual Fire Insurance Company commenced a general research upon oils and their relation to losses by fire, the results of which, as made public by the company, are embraced in a lecture given before the New England Cotton Manufacturers' Association at their semi-annual meeting held October 30, 1878, by Professor J. M. Ordway, of the Massachusetts Institute of Technology, (*e*) and in a paper presented by Mr. C. J. H. Woodbury to the American Association for the Advancement of Science at their meeting in Boston in 1880, and published in their proceedings for that year. From these two papers as embodying the latest results obtained, which are emphasized by the test of actual experience, I shall quote liberally.

The contract under which Professor Ordway undertook this research required that the investigation should have reference to—

1. The power of the oils to diminish friction under various pressures and at various rates of speed.
2. The tendency of the oils to oxidize while in use for lubrication, and their consequent deterioration in efficiency.
3. Their tendency to rapid oxidation when largely extended by absorbent fibrous substances, and their consequent liability to induce spontaneous combustion.

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a W. B., 1879, 1139.

b *Die Prüfung der Schmiermaterialien*, Ed. Donath, Leoben, 1879, Otto Protz.

c *Die Prüfung von Schmierölen;* M. Albrecht, Riga, 1879, G. Deubner. Hübner's Zeitsft., 1879, 67.

d *Friction and Lubrication.* Determination of the laws and coefficients of friction by new methods and new apparatus, by R. H. Thurston: London, 1879. Trübner & Co.

e Proceedings of the semi-annual meeting, held at Boston, October 30, 1878.

4. Their proneness to emit combustible vapors when rubbed or moderately heated, or kept long in partially-filled reservoirs.
5. Their tendency to corrode metallic bearings.
6. Their specific heat, or relative rapidity of heating and cooling when exposed to the same heating or cooling influence.
7. The relative length of time that a pint of each will last in doing a given kind of lubricating work.
8. Their relative fluidity or the thickness of layers retained between two surfaces subjected to a given pressure.
9. Their compatibility with each other when successively used on the same bearing.
10. Liability to separate into constituent parts by long standing or by freezing.
11. Their freedom from non-lubricating sedimentary matter.
12. Ease of removal from bearings after becoming thickened by floating dust or abraded particles of metal, or by accidental over-heating.
13. Their tendency to diffuse unpleasant or unwholesome odors.
14. Ease of ignition and rapidity of combustion when they are inflamed.
15. The probability of perfect uniformity in successive lots supplied by the manufacturer.
16. The possibility of securing an unlimited supply at moderate prices.
17. Suitableness for oiling wool before weaving and spinning.
18. Ease of removal from yarn or cloth in the operations of scouring.
19. Their suitableness for the manufacture of soaps.
20. Their effect on leather and wool.

Professor Ordway remarked that the report he had to make referred particularly "to certain chemical properties and the facility of oxidation of different oils". His samples were procured directly from the mills using them, and were referred to him marked with numbers; the examination, therefore, was entirely unprejudiced. A few additional samples were procured from reliable manufacturers, and samples were imported from Paris, France. These were used in comparison. After the examination was well under way a list of names was furnished him, so that in his report he was able to give the oils the names by which they were known in commerce. Of the one hundred and eighteen oils in the list twenty-four were designated "spindle" oil, some of which were called "light" and some "heavy", fourteen as sperm, eleven as lard, nine as paraffine, five as machinery, three as olive, three as stainless, two as neat's-foot, six as wool oils, five as mixtures of paraffine and sperm, three as mixtures of paraffine and neat's-foot, and two as mixtures of sperm and spindle.

Section 2.—SPECIFIC GRAVITY.

Sections 2, 3, 4, and 5 are largely quotations from an extemporaneous lecture by Professor Ordway, which constitutes the best statement of the subject that has yet been made public.

A simple test of oils, but one of exceedingly limited value, is the specific gravity. We have determined the density of nearly all by cooling to 60° F. and weighing in a flask of known capacity. The results are as follows:

"SPINDLE" OILS.

No. 17 = 0.840	No. 21 = 0.880	No. 71 = 0.890
51 = 0.848	9 = 0.886	16 = 0.890
76 = 0.848	52 = 0.887	79 = 0.893
74 = 0.850	31 = 0.887	80 = 0.894
4 = 0.850	47 = 0.890	87 = 0.898
66 = 0.870	49 = 0.890	38 = 0.913
68 = 0.880	53 = 0.890	48 = 0.916

"SPERM" OILS.

No. 11 = 0.880	No. 44 = 0.886
26 = 0.880	75 = 0.886
28 = 0.880	77 = 0.886
32 = 0.880	35 = 0.887
54 = 0.880	40 = 0.890
56 = 0.880	34 = 0.890
58 = 0.886	36 = 0.896

These agree very closely with the true sperm oils which were procured from disinterested persons or from the shops. I got several specimens from cargoes newly arrived, taken from the casks before the vessels were unloaded, and these varied in specific gravity from 0.877 to 0.888, the latter being crude head oil, rich in spermaceti. So, if specific gravity is any indication, the oils sold as sperms are very much like genuine sperm.

"PARAFFINE" OILS.

No. 65 = 0.880	No. 27 = 0.905
59 = 0.884	45 = 0.905
85 = 0.888	69 = 0.905
63 = 0.890	2 = 0.910
43 = 0.894	

"LARD" OILS.

No. 10	= 0.914	No. IV	= 0.918
19	= 0.916	VII	= 0.918
13	= 0.917	VI	= 0.920
81	= 0.917	Pure lard	= 0.919

"STAINLESS" OILS.

No. 3	= 0.860	No. 1	= 0.890
70	= 0.874		

"NEAT'S-FOOT" OILS.

No. 50	= 0.910	No. 6	= 0.914
Pure neat's-foot	= 0.920		

MACHINERY OILS.

No. 86	= 0.878	No. 61	= 0.895
39	= 0.878	24	= 0.899
33	= 0.887		

With regard to other oils than sperm, specific gravity gives no definite indication, because mineral oils may be mixed, and in that way we may get an oil of high density, yet containing oil of low specific gravity. All I can say at present is that sperm oil is very light, of about specific gravity 0.880; and lard oil should have a specific gravity of about 0.920. Lard oils are pretty thick, and petroleum oils of about the same specific gravity are also thick, and neither density nor thickness would betray an admixture. Though a great many people rely on the specific-gravity test, it is not to be depended on by itself, though it may occasionally be useful in connection with other tests.

Section 3.—CONTENT OF VOLATILE MATERIAL.

As to the mineral oils, we soon observed that they are some of them volatile at the ordinary temperature of the air. It is somewhat the same with petroleum oils as with water. Water evaporates at all temperatures, from the freezing point up, and so do the petroleum oils. Those that have a high boiling point do so very little, indeed; but those having a low boiling point, if left in the air in the latter part of June or July, evaporate completely in two weeks. This was rather a striking thing, as showing that it is unsafe to leave these oils exposed to the air, where there is much surface exposed, in a warm room, for we may get an explosive vapor over the whole, and if any one goes near it with a lamp there will be trouble. But this was carried further. What takes place at the ordinary summer temperature will take place more rapidly at higher temperatures; and in making our experiments we must exaggerate a little, in order to get quickly at results. Therefore we put some of these oils into an oven and observed how much they lost in twelve hours. This, I believe, is a somewhat new line of investigation, and the results are rather striking. Some of them were left for four hours, some for eight hours, and some for twelve hours; but we have finally settled upon twelve hours and 140° F., which is not a very high temperature, and which we may often have near a steam-pipe; and, in order to prevent one trouble which occurs in testing oils in this manner, we were obliged to suck up the oil in filtering paper. If you pour some oil into a watch-glass it will in time creep over the edge, and a little will be lost, and we suffered somewhat from that circumstance. We found it better to take a small watch-glass, which had been weighed carefully, and pour in oil enough to saturate a bit of paper; the paper prevents the creeping. So, in making these experiments, we took a watch-glass, put into it a piece of dry filtering paper about two-thirds as large, weighed the whole, dropped in some oil, weighed it, and put the glass into a hot oven at 140°, and observed the loss. All of the oils have been tried in this manner, and some of them give results which, to say the least, are very striking. * * * The first one was a spindle oil, at 50 cents per gallon; it lost only 1.3 per cent. The next was a spindle oil that lost 1.5 per cent., and the amount gradually increases, so that in the 43d of the table we come to an oil that lost 10 per cent. * * * And again, the percentage rises to the last, a so-called "spindle oil", at 48 cents per gallon, which lost nearly 25 per cent. What would you think of an oil which lost, by exposure to a heat which is not very great, 24.6 per cent. in twelve hours? It seemed as though all the oils which lost over 10 per cent. must be oils not to be recommended, to say the least. I think the insurance companies would say they ought to be condemned; and there is a pretty large number of such oils among those which were examined. There are twenty out of the one hundred and eighteen which lost over 10 per cent. by exposure to this moderate temperature. When the temperature is carried up to about 200° the loss in some cases was about 37 per cent. Of course it is a matter of judgment which of these should be considered safe and which should not. For my own part, I should rather not use any oil which evaporated over 5 per cent. under such circumstances. This matter has some connection with the flashing point, as one would suppose, and the flashing point is the test which has been most relied on in regard to petroleum oils. I should say, in speaking of these oils, that those that are marked sperm and lard and neat's-foot, instead of losing, gained at most 2½ per cent.—they gained all the way from nothing to 2½ per cent. All the oils of animal and vegetable origin (I mean those which were so marked) lost nothing, but gained a little. In some cases they may have been mixed with a small quantity of petroleum oil. We find that, in the case of a heavy petroleum oil mixed with a light petroleum oil, we may expose the mixture to the boiling point of the latter oil without evaporating much. The heavy oil has a power of holding back.

Section 4.—THE FLASHING POINT.

Now the flashing point is a matter which is determined in the case of ordinary kerosene very easily by heating the oil in a water-bath. In the case of these lubricating oils we must resort to a higher temperature and put them in an oil-bath. In this case we take a beaker, * * * hang it in oil, and expose it to a gradually raised temperature, until when we wave a small flame over the surface there will be a slight explosion. The flashing point of all the oils under examination is considerably above the boiling point of water, but some of them are not above the point to which oils might get in contact with the steam-pipe, or pretty near a pipe heated by high-pressure steam; and we all know that in factories, and in various other places, there is a possibility of oils, as well as other things, dropping upon the steam-pipe, or coming very close to the pipe itself. Of course such an oil, with such a flashing point, would be liable under such circumstances to diffuse an explosive vapor in the room. Perhaps, under any ordinary circumstances, it would not take fire, but under

some circumstances it is liable to particular danger; for it so happens in a great many of these experiments, when we want to get an accident, we cannot do it, and we have to wait until nature takes its own course. I remember some years ago trying to get an explosion with ordinary kerosene, and we found it extremely difficult, and with kerosenes which are of low flashing point it is difficult to get a condition of things in which an explosion will take place; but we know that these explosions are happening every day. With regard to the flashing points, we have tried all; we have tried, by way of comparison, a great many of those which we procured directly from the manufacturer, and which we suppose we know something about. The flashing points vary from 239° to 450° F., but on putting the figures side by side with those that represent the loss by evaporation we find the flashing point does not indicate the loss we should expect by evaporation. There is a wonderful difference. I find there is one which lost by evaporation 4.6 per cent., and it had the same flashing point as one that lost by evaporation 13.8 per cent. We find another one which lost 9.4 per cent., and yet it flashed at the same heat as one that lost 24.6 per cent. by evaporation. This would seem to show that the flashing point is not to be so much relied upon. I place a good deal more reliance on the other experiments, to long exposure in contact with the air at a given temperature; and the flashing point I should set down as one of the things that may give uncertain results. If any oil has a low flashing point it ought to be rejected; but, at the same time, an oil bearing a high flashing point may be mixed with a certain amount of a lighter oil, which will freely evaporate when exposed to the air more rapidly than another oil with a low flashing point.

Section 5.—SPONTANEOUS COMBUSTION.

Of course those oils, which, on being exposed twelve hours to a high temperature (140°) gain something, gain it from the air on oxidation; and they are found to be, as a general thing, either of animal or vegetable origin. * * * I believe the sperms gain rather more than the lard or neat's-foot. Of course this oxidation is a matter which is of considerable importance with reference to spontaneous combustion; and we have attempted to make experiments on spontaneous combustion, which is a matter depending on the oxidation of oil when spread out over a great surface. We imbibe fibers with the oil in such a way that they are not dripping with the oil, but simply dampened with it, and then expose them to hot air, and in the course of time, whether the fiber is cotton, or jute, or wool—in time they will all take fire when we have used an animal or vegetable oil. It is rather difficult to carry out these experiments on a small scale, because we use only a handful; but when you have a large basketful of waste there is no difficulty. In order to make up for the tendency to loss it was necessary, of course, to heat the soaked waste to a temperature which might be considered rather high. We have made experiments at 140° F., and we have made them at 190°, and we have made them above the boiling point of water; in all cases it was below the igniting point of the oils. To make experiments on spontaneous combustion we took a given weight of cotton-waste, about a handful, and imbibed it with its own weight of the oil to be tried; for it is quite an important matter that the experiments should be made with the same quantity of oil, and that the oil should be spread out in the same way throughout. When the waste is imbibed with its own weight it does not appear very greasy. It is not in a dripping condition, but in a state where it is still ready to imbibe. It is said by those who have made such experiments in Europe that equal weights of cotton and oil are the best; and I should suppose that to be the case, as then the air has the freest access to a large surface of the oil. The cotton, of course, is only matter which serves to spread out the oil, and to act as a non-conductor to prevent the heat from being radiated. We made experiments on spontaneous combustion at 200° and at 220°, but not as many of them as could be desired.

One of the important things was to determine the accuracy of the trials made in Europe a few years ago. There were some experiments, published in the *Bulletin of the Industrial Society of Mulhouse*, in 1875 and 1876, experiments made by Mr. Coleman, of Glasgow, and by Dolfus, in Alsace. The experiments of these gentlemen show that when an animal or a vegetable oil is mixed with a small percentage of petroleum oil the tendency to spontaneous combustion is diminished very much, and if with a large quantity of mineral oil the spontaneous combustion refuses to take place. There is, however, in this latter case an oxidation. They found in their experiments, when they took an oil which consisted of thirty parts of petroleum and seventy parts of an animal or vegetable oil, that the oil would heat up when exposed to steam heat, but when it arrived at a certain point it would go down. There is an oxidation, therefore, in such a case; but the petroleum prevents its oxidizing so fast as to allow the heat to accumulate and set the mass on fire. This, of course, is a very important point; and it was important to determine whether their results apply to the oils we have as well as those commonly met with in Europe. They use more vegetable oil, whereas sperm oil does not seem to be so common there as it is here. They found that all the oils tried by themselves would undergo spontaneous combustion, but when they contained from 30 to 50 per cent. of a mineral oil spontaneous combustion would no longer take place under the circumstances to which they exposed them.

We have made experiments with cotton-waste and cottonseed oil mixed with petroleum oil, and have found that cottonseed oil mixed to the amount of 25 per cent. with 75 per cent of petroleum oil will take fire spontaneously; so it seems that although spontaneous combustion is retarded in a great degree, it is not entirely prevented, even by a pretty large admixture of petroleum oil in the case of such oils as cottonseed and linseed, which are peculiarly prone to oxidation. When we came to take lard oil a careful experiment was made, which showed that 33 per cent. of petroleum oil (for this purpose what is commonly called spindle oil was taken) mixed with 67 per cent. of lard oil would not undergo spontaneous combustion at the temperature at which the experiment was made; whereas with 32 per cent. it did undergo spontaneous combustion. It would be very desirable to carry out these experiments to that degree of nicety in all cases, but you can easily see, when we are obliged to expose these oils to long-continued heat, and have an apparatus which must be isolated from the wood work around, we cannot have a great many of them going on at a time, and an experiment lasts from six to eight hours. Generally it takes to finish up one of these experiments on spontaneous combustion six hours. Some of them will take fire in three hours, but the heat does not accumulate enough with most until they have been kept in the oven for five or six hours. A great deal remains to be done in this line. * * * We all know cottonseed oil is one of those oils we have to fear, and it happens to be one of those whose spontaneous combustion cannot be prevented by a slight admixture of petroleum oil. But the experiments of Dolfus (*a*) and Coleman (*b*) were correct, it seems. We had no reason to doubt they were correct, but the experiments we made were made at a little higher temperature; and although the oil, mixed in the proportion of 70 parts of oil and 30 of petroleum oil, may not take fire spontaneously when the temperature is maintained at 110° F., yet it may when it is maintained at 190° F.; and, of course, cotton-waste is liable to be exposed sometimes to a steam heat, and a steam heat may range up to 300° F., so that even when the oils are mixed with petroleum oil there is danger. Still, it is a fact that the admixture of even 10 per cent. of one of the heavy petroleum oils does diminish very much the tendency to oxidation or to spontaneous combustion, and that is a fact, of course, of immense importance. * * * We have tried the different animal and vegetable oils, some of them mixed with larger or smaller proportions of petroleum, but that investigation is still unfinished.

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a *Bull. Soc. Ind. de Mulhouse*, 1876.

b C. N., xxx, 147; W. B., 1871, 1874, 1875.

SECTION 6.—FLUIDITY.

There is another matter which might be of some importance, but we have not been able to deduce from our trials any data of practical value; that is, the relative fluidity of the oils. There is a wonderful difference in this respect, and we found all the lighter oils, that is, the lighter paraffine and spindle oils, are very much more fluid than the sperms of corresponding specific gravity. The specific gravity and fluidity have little relation to each other; there is some, but no exact correspondence. (*a*) The mode of experiment for this purpose is to take a small pipette, of which the globe holds about a cubic inch. The globe is filled by sucking the oil up to the neck, and the liquid is then allowed to flow out through a very small aperture thirty-seven thousandths of an inch in diameter, and the time of flow is noted. The experiments must be made in a room which is kept at a uniform temperature.

In this way ran out—

	Min.	Sec.
Sperm	3	43
Linseed	5	42
Poppy	6	49
Cottonseed	7	31
Sesame	8	14
Lard	9	24
Olive (mere *goutte*)	9	26
Neat's-foot	9	29
Rape	9	55
Navette	10	9
Colza	10	0
Castor, over two hours.		

There is another point which we would like to draw some deductions from if we could, but so far we have not found any particular law. If we immerse wicks in these oils, or filtering paper, which amounts to the same thing, of course, the distance which the oils will ascend or be carried up by capillary attraction is a matter depending on the fluidity of the oil, and this does not seem to have any exact relation to the flowing out through a small aperture. It is contrary to what I should have expected. * * *

SECTION 7.—CHEMICAL TESTS.

There have been various chemical tests proposed from time to time for oils, but in our investigation we were obliged to go on the supposition that almost nothing had been done, from the simple fact that the oils which have been experimented on in former times, in France particularly, have been mixed, and oils which are no longer in use. (*b*) We have experiments relating to the adulterations of olive oil and linseed oil and rape, but those adulterations are out of fashion, and they used certain tests which give comparative indications only; there is nothing absolute about them. One of these tests is nitrate of mercury, which acts simply from containing in solution a certain quantity of nitrous acid. Another test is strong oil of vitriol, and another is caustic soda, and another is chloride of zinc. We can get very little aid or comfort from these old experiments. The nitrate of mercury test is of some trouble to carry out. And finally a very much better fluid has been invented by Jules Roth. He used a fluid which absorbs nitrous acid in considerably larger quantities than nitrate of mercury, and which could be kept for a considerable length of time. It is made by passing nitrous fumes, formed by acting on lumps of iron with nitric acid, into sulphuric acid at 46° B. The charge up of the acid takes some eight, ten, or twelve days. It is a slow operation, but when it is well carried out you get a greenish or bluish liquid, which has a wonderful effect on some oils, and although there is nothing absolute to be learned by this, it gives comparative indications of great value. It seems that all those oils that oxidize readily are not effected by this test, whereas those that keep better, that are not so prone to grow rancid, will thicken and become quite hard when tested with it.

In making these experiments we generally take a small wine glass and put in a little of the liquid and about the same amount of the oil that is to be examined, and then they are whipped together and allowed to stand for some time. If the oil is a good one, one that doesn't oxidize readily, we shall find that the product is very stiff; even if you turn it upside down very little liquid will come out, and it is more like wax or tallow than the original oil. The sample I have in my hand is olive; this is good olive oil, and you may see from the appearance of this that I find considerable difficulty in pushing a rod into it; it is as stiff as beef tallow. Good olive oil will do this, but if adulterated with even 1 per cent. of these other oils the product is softer. Olive oil hardens very readily indeed, and good lard oil also hardens with promptness. This is a specimen of lard oil; I can push the rod through this without very much trouble. Here is one that is mixed with 5 per cent. of petroleum. You will observe on comparing these two that the petroleum oil has undergone such a change that it is colored yellow. The color indicates something. Here the lard oil is thoroughly white and will remain so; whereas if there is an admixture of petroleum oil, however little, it will be pretty sure to turn yellow, and the product is softer than the other. I have here another which is a mixture of cottonseed and olive oil. Here you see a perfectly fluid oil; there is a little thickening from the acid below, but it still remains in a fluid condition; and this contains one-third of cottonseed and two-thirds of olive. By taking great pains we can distinguish 5 per cent. of admixture very well.

These, of course, for illustration, have been exaggerated a little bit. That is, I have taken larger quantities than would be necessary if I were going to make an exact trial to determine how much can be used without interfering with the fluidity. I have here a mixture of lard oil with 20 per cent. of cottonseed that has thickened, but not very much. Now, when we take this same test and apply it to rape-seed oil, it remains perfectly fluid. Of course rape-seed oil, were it mixed with olive or lard oil, would diminish the consistency of the product very much indeed. Here is neat's-foot oil. One would suppose it would be very much like lard, but it is not; it remains fluid without the oxidation surface or crust. This hardening usually takes place in the course of six or eight hours. The best way is to let them stand and watch them and see at what rate the hardening goes on. If you find one hardens in four hours, you will find that it is a pretty good olive or lard oil; if it is six hours, it may be mixed; if it is eight hours, it is more likely to be mixed, and sometimes it is necessary

a An oil distilled from California malthas of a specific gravity of 16° B. flowed like an essential oil.—S. F. P.

b This statement of Professor Ordway explains why the investigations that have been made prior to the last few years are of so little value at present.

to let them stand until the next day; then we have a little hardening. (*a*) In the case of petroleum oils we have a very peculiar effect. Here is one of them: it has become very highly colored; the petroleum oil itself becomes colored, and the fluid below becomes colored, and we can distinguish it by this discoloration. And there is another test, too. Whenever you have whipped up a petroleum oil with this liquid, and have let it stand for some hours, ten or twelve hours, there will be a matter like this sticking to the rod; a waxy, sticky substance, something that is neither oil nor wax; it is not paraffine; precisely what it is I don't know; it is a matter which still remains to be investigated. All of the petroleum oils that we have examined, without exception, I think contain more or less of the matter which gives this precipitate, and the heavier the oil the greater the amount of the precipitate; but even the light spindle oils and kerosene itself will show a definite coating on the rod or else a definite coating on the surface of the liquid itself. We have here a test in Roth's liquid, which is a very good indication of something. We cannot say positively when we have an oil hardened in this way what the oil is, but we can say what it is not, and that sometimes is a very important thing. If it purports to be so and so, we can see whether it is so and so or something else. * * *

Mr. ATKINSON. I should like to put one question at this point to Professor Ordway that I think is important. I believe you have reached the conclusion in respect to the amount of that gummy substance in a petroleum oil that it largely depends on the point to which the distillation has been carried, and that the double distilled and refined oils contained the least? * * *

Professor ORDWAY. That is so; there are specimens here to show that. There is one here which has been distilled once, and another which has been distilled twice. It cannot be seen across the room; but if any one examined these closely he will see that the precipitate on the surface of the liquid below is greater in one case than in the other, and the discoloration is about the same.

Mr. ATKINSON. I think I am also right in asking you whether or not that is not the substance which probably causes the staining of the cloth and the varnishing of the windows and of the polished parts of the machinery?

Professor ORDWAY. It may be that substance. I should not be willing to say positively it is until we have made further experiments. This is a subject which has not been investigated, I believe; and it is quite important that we should spend time and find out what it is. It is something objectionable, it seems to me. It is said by some of the manufacturers of paraffine oil that a little of this in an oil does no harm; but that is not a point we should take for granted. While it may not do any harm in respect to lubrication, it may have something to do with the staining. Here is a substance which is got on oxidation. It has kept on turning brown, and that brownness may go on to a certain point where it will effect a permanent stain on the cloth. I am reasoning theoretically, but I think there are good grounds for saying, if an article of this sort is allowed to stain cotton or wool, and allowed to remain for some time, this substance will become precipitated and go on oxidizing and make a permanent defect. This is a point which it is very desirable to have further light on; and we can only get at it by a long series of trials, for the amount which we get of this is not very great. This is a body which is carried forward by the vapor; for all vapors have a great carrying power, and although the boiling point of this substance is probably very high when oils are distilled, a little is carried forward even by kerosene itself.

There are other chemical tests which so far we haven't had the time really to carry out. * * * Among other things it would be desirable to find out something by saponification, and experiments in saponification are slow. We generally have to boil for ten, twelve, or even fifteen hours; and, when you undertake to saponify a dozen oils, you see it would take a good many individuals to carry on those experiments in a short time. * * * There has one thing turned up which I was not aware of before: that sperm oil does not saponify readily. We have taken pure sperm oil, and we find it is exceedingly difficult to saponify more than 47 or 48 per cent. of it. I mention this because some might be tempted, after making an experiment of this sort on an oil of an unknown origin, to think it was not a sperm oil. This peculiarity arises, I suppose, from a difference in the composition of sperm from other oils. Precisely what it is I don't know, because there has been very little written on the subject of sperm oil; and it opens up, unexpectedly to me, a new field for investigation, and I think the character and quality of sperm oil ought to be investigated by scientific men. Here is this fact which is admitted by a great many people: that sperm oil, of all the animal and vegetable oils, is the best lubricator. It is not because it contains more oleine, but it is something in the character of the oleine. After we have eliminated all the spermaceti, we get a peculiar oil which is different from the other animal oils, but I think it is *sui generis*. We have saponified a great many of the oils. Those which saponify with most ease are lard oils. Neat's-foot saponifies pretty readily. When we take those that are mixed with petroleum, we can saponify all the way from 5 per cent. up, according to the proportion of the petroleum. I am not able at present to give any particular directions about saponification, for this is a matter which requires to be understood so as to present it to people in ordinary life, and I think it can be made a very good test of the character of oils, but in order to do it there must be a great deal of experiment. * * * At present all I can say is, a good many of the oils we have examined saponify very readily; and these turn out to be, according to the descriptive lists, lard oil or something similar to lard oil. There are a good many of them which didn't saponify at all; and, on reference to descriptive lists, they are found to be paraffines.

When the oils are poured on a brass plate and allowed to run slowly down for a length of time some of them get quite green; they color the brass; they are decidedly acid in their character. In looking over these results I noticed that all the oils which are acid are either sperm or neat's-foot, and all of the sperm—I mean all those that purport to be sperm and neat's-foot—are acid in their character, whereas the other (the petroleum oils) don't show any acid reaction. (*b*)

Following the close of Professor Ordway's remarks, Mr. Edward Atkinson and the professor engaged in a discussion of the practical value of the flashing and evaporation tests as applied to lubricating oils. The following is a summary of their conclusions: The flashing point is no indication of the lubricating power of an oil, but has an important bearing on insurance. No oil should be used about a manufacturing establishment that "can diffuse from the bearings an explosive vapor into the atmosphere". While there are some manufacturers of oils that can be depended upon, it is found that oils purporting to come from some others differ widely in quality. Several specimens of oil having the same name differ greatly in flashing point and other characteristics, yet the price remained about the same, and was evidently intended for the same article. While it appears to be difficult for unskillful manufacturers to prepare oils of uniform quality, there are others whose product varies but slightly, and it was somewhat remarkable that some of them having the low flashing point were high-priced, while others having a low flashing point were

a I have quoted Professor Ordway fully, although the text does not relate to petroleum, because of the great value of his experiments.

b This long quotation, reported from an extemporaneous lecture, and consequently somewhat diffuse in style, has been introduced here as the best statement of the subject treated that has yet been made public.—S. F. P.

among the lowest-priced oils on the market. It was found that many of the best managed corporations, ignorant of their true character, were using oils with a high flashing point. But, in addition to the element of safety from the use of these oils, which rapidly evaporate, is found the question of profit.

The cost of oil per 1,000 pounds of cloth of about No. 33 yarn, in mills in which there is no reason in the character or kind of machinery for a variation exceeding 25 per cent., appears to vary from 68 cents to $2 58 per thousand, while the quantity used varies from 1.03 to 3.36 gallons per 1,000 pounds. It does not appear that this variation has any particular connection with the price of the oil. * * * But since we have begun to compare the results of the tests of evaporation and flashing point a very distinct relation of these tests to the actual cost of oil per 1,000 pounds of cloth is foreshadowed, and if we can establish this rule a great point will have been gained.

The following striking illustration is given of the probable effects of the use of a lubricating oil from which the volatile material had not been completely removed: (*a*) The fire caught in the basement and communicated with striking rapidity with a weaving-room up one flight of stairs in which woolen fabrics were being woven and in which there were "no peculiarly combustible conditions". The flames flashed instantly from one end of the room to the other, striking like a stroke of lightning the gas-meter, placed on a shelf some six or eight feet from the floor at the farther end of the room, melting all the solder, and dropping the connecting pipes from the meter, while a towel that was hanging 2 feet under it was not scorched. The wool oil and the lubricating oil being both examined, the former was found to be pure lard oil, while the latter was one which had evaporated from the evaporation plate completely in five days. There was an oil on those bearings in that woolen weaving-room that did evaporate with extreme rapidity; there was a fire that flashed through the room giving the appearance of flames. Of course evaporation is waste, and is not only injurious, but unprofitable.

The following paper, upon the "Separation of Hydrocarbon Oils from Fat Oils", by Alfred H. Allen, is given here as the latest and best English contribution to the literature of this subject: (*b*)

The extensive production of various hydrocarbon oils suitable for lubricating purposes, together with their low price, has resulted in their being largely employed for the adulteration of animal and vegetable oils. The hydrocarbons most commonly employed for such purposes are:

1. Oils produced by the distillation of petroleum and bituminous shale, having a density usually ranging between 0.870 and 0.915.
2. Oils produced by the distillation of common rosin, having a density of 0.965 and upward.
3. Neutral coal-oil, being the portion of the products of distillation of coal-tar boiling at about 200° C., and freed from phenols by treatment with soda.
4. Solid paraffine, used for the adulteration of beeswax and spermaceti, and employed in admixture with stearic acid for making candles.

The methods for the detection of hydrocarbon oils in fat oils are based on the density of the sample, the lowered flashing and boiling points, the fluorescent characters of the oils of the first two classes, and the incomplete saponification of the oil by alkalies. The taste of the oil and its odor on heating are also useful indications.

If undoubtedly fluorescent, an oil certainly contains a mixture of some hydrocarbon, but the converse is not strictly true, as the fluorescence of some varieties of mineral oil can be destroyed by chemical treatment, and in other cases fluorescence is wholly wanting. Still, by far the greater number of hydrocarbon oils employed for lubricating purposes are strongly fluorescent, and the remainder usually become so on treatment with an equal measure of strong sulphuric acid.

If strongly marked, the fluorescence of a hydrocarbon oil may be observed in presence of a very large proportion of fixed oil, but if any doubt exists the hydrocarbon oil may be isolated. As a rule, the fluorescence may be seen by holding a test-tube filled with the oil in a vertical position in front of a window, when a bluish "bloom" will be perceived on looking at the sides of the test-tube from above. A better method is to lay a glass rod, previously dipped in the oil, down on a table in front of a window, so that the oily end of the rod shall project over the edge and be seen against the dark background of the floor. Another excellent plan is to make a thick streak of the oil on a piece of black marble or glass smoked at the back, and to place the streaked surface in a horizontal point in front of and at right angles to a well-lighted window. (*c*) Examined in this manner, a very slight fluorescence is readily perceptible. If at all turbid, the oil should be filtered before applying the test, as the reflection of light from minute particles is apt to be mistaken for true fluorescence. In some cases it is desirable to dilute the oil with ether and examine the resultant liquid for fluorescence. An exceedingly small amount of mineral oil suffices to impart a strong blue fluorescence to ether.

The quantitative analysis of mixtures of fat oils with hydrocarbon oils has till recently been very uncertain, the published methods professing to solve the problem being for the most part of very limited applicability, and in some cases wholly untrustworthy.

When the hydrocarbon oil in admixture happens to be of comparatively low boiling point, it may often be driven off by exposing the sample to a temperature of about 150° C., but the estimation thus effected is generally too low, and often quite untrustworthy.

When it is merely desired to estimate approximately the proportion of hydrocarbon oil present, and not to isolate it or examine its exact character, Kœttstorfer's titration process may be used, as suggested by Messrs. Stoddart. But the best and most accurate method of detecting hydrocarbon oils in, and quantitatively separating them from, fat oils, is to saponify the sample, and then agitate the aqueous solution of the soap with ether. (*d*) On separating the ethereal layer and evaporating it at or below a steam heat the hydrocarbon oil is recovered in a state of purity.

Either caustic potash or soda may be employed for the saponification, but the former alkali is preferable, owing to its greater solubility in alcohol and the more fusible character of the soaps formed. A convenient proportion to work with consists of 5 grms. of the sample of oil and 25 c. c. of a solution of caustic potash in methylated spirit, containing about 80 grms. of KHO per liter. Complete saponification

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a In this case the volatile oils appeared to constitute the bulk of the lubricator used.

b *Oil and Drug News*, October 18, 1881. Read at the 1881 meeting of the British Association.

c "Either of these plans is infinitely superior to the polished tin-plate usually recommended. In short, the background should be black, not white."

d "According to my experience, treatment of the dry soap with ether, petroleum spirit, or other solvent is liable to cause error from solution of the soap itself, if much hydrocarbon oil be present."

may usually be effected by boiling down the mixture in a porcelain dish, with frequent stirring, until it froths strongly. In the case of butter, cod-liver oil, and other fats which undergo saponification with difficulty, it is preferable to precede this treatment by digestion of the mixture for half an hour at 100° C. in a closed bottle. After evaporating off the alcohol, the soap is dissolved in water, brought to a volume of 70 to 80 c. c., and agitated with ether. The ethereal solution is separated, washed with a little water, and carefully evaporated The agitation with ether must be repeated several times to effect a complete extraction of the hydrocarbon oil from the soap solution.

The foregoing process has been proved to be accurate on numerous mixtures of fat oils with the hydrocarbon oils. The results obtained are correct to within about 1 per cent. in all ordinary cases. In cases where extreme accuracy is desired, it is necessary to remember that most, if not all, animal and vegetable oils contain traces of matter wholly unacted on by alkalies. In certain cases, as butter and cod-liver oil, this consists largely of cholesterin, $C_{26}H_{44}O$. (*a*) The proportion of unsaponifiable matter soluble in ether, which is naturally present in fixed oils and fats, rarely exceeds 1½ per cent., and is usually much less. Sperm oil, however, constitutes an exception, yielding by the process about 40 per cent. of matter soluble in ether. (*b*) This peculiarity has no practical effect on the applicability of the process, as sperm oil, being the most valuable of commercial fixed oils, is never present without due acknowledgment of the fact. Spermaceti and the other waxes yield, after saponification, large percentages of matter to ether, and hence the process is not available for the determination of paraffine wax in admixture with these bodies, though it gives accurate results with the mixtures of paraffine and stearic acid so largely employed for making candles. The following figures, obtained in my laboratory by the analysis of substances of known purity and of mixtures of known composition, show the accuracy of which the process is capable. The process was in each case on about 5 grms. of the sample in the manner already described.

The results are expressed in percentages:

Composition of substances taken.				Unsaponifiable matter found.
Fat oil.	Results.	Hydrocarbon oil.	Results.	
	Per cent.		*Per cent.*	*Per cent.*
Olive	40	Shale oil	60	58.03
Olive	80	Shale oil	20	19.37
Olive	40	Rosin oil	60	59.42
Olive	80	Rosin oil	20	19.61
Rape	86	Shale oil	16	15.95
Cottonseed	60	Rosin oil	40	39.74
Linseed	60	Rosin oil	40	39.32
Castor	60	Rosin oil	40	38.88
Cod-liver	70	Rosin oil	30	30.80
Cottonseed	48	Coal-tar oil	52	52.60
Lard	60	Paraffine wax	40	39.54
Lard	20	Paraffine wax	80	80.09
Olive	100			*1.14
Rape	100			*1.00
Castor	100			0.71
Cod-liver	100			1.82
Palm	100			0.54
Butter fat	100			0.46
Sperm	100			41.49
Spermaceti	100			49.68
Japan wax	100			1.14
Lard	100			*0.23
Cacoa butter	100			0.22

* These experiments were not made strictly by the same process as the majority.

The following table indicates the general behavior of the constituents of complex fats, oils, and waxes when the aqueous solution of the saponified substance is shaken with ether:

Dissolved by the ether.	Remaining in the aqueous liquid.
Hydrocarbon oils; including—	Fatty acids. } In combination with the alkalies used.
Shale and petroleum oils.	
Rosin oil.	Resin acids. } In combination with the alkalies used.
Coal-tar oil.	
Paraffine wax and ozokerite.	Carbolic and
Vaseline.	*c* Cresylic acids. } In combination with the alkalies used.
Neutral rosins.	
Unsaponified fat or oil.	Glycerol (glycerine).
Unsaponifiable matter; as cholesterin.	
Spermyl alcohol; from sperm oil.	
Cetyl alcohol; from spermaceti.	
Myricyl alcohol; from beeswax.	

The hydrocarbon oil having been duly isolated by saponifying the sample and agitating the solution of the resultant soap with ether, its nature may be ascertained by observing its density, taste and smell, behavior with acids, etc.

a "The process affords a very rapid and simple means of isolating cholesterin. Thus, on dissolving the traces of unsaponifiable matter left by butter in a little hot alcohol, and allowing the liquid to cool, abundant crystals are deposited, which may be identified as cholesterin by their microscopic and chemical characters. A sample of butterine gave no cholesterin."

b "I am investigating this interesting fact, and have obtained full confirmation of Chevreul's observation that sperm oil when saponified yields a peculiar solid alcohol instead of glycerine. It is distinct from cetyl alcohol, and distills, apparently without decomposition, at a very high temperature."

c "In a previous research I found that carbolic and creslyic acids were wholly removed from their ethereal solutions by agitation with caustic soda."

Section 8.—PRACTICAL RESULTS OF THE INVESTIGATIONS OF PROFESSOR ORDWAY.

In a circular issued in 1880 Mr. Edward Atkinson treats the subject of oil as follows:

In the two years and little more that have elapsed since the question was taken up for the mere purpose of abating some of the dangers of fire the following changes have occurred. * * * In 1878 a request made for information was responded to by the managers of one hundred mills, who gave the quantity and price of the oils used for lubrication, the pounds of cotton goods manufactured in preceding periods of six or twelve months, and other data. These returns were compiled, and it appeared that in fifty-five mills, operated on about the same fabric, and among which there was no good reason for a variation of over 20 per cent. either in cost or quantity of oil used, the actual variation was about 350 per cent. It will also be remembered that a large portion of the waste of oil consisted in evaporation, whereby the atmosphere was sometimes charged with combustible vapors, by which some fires that might otherwise have been easily subdued were made very dangerous. It was for the special purpose of discovering the facts in this particular matter and applying the remedy that the inquest was first entered upon.

It is a great satisfaction to be able to state that within the first year after we agitated this subject a settlement was made in a patent lawsuit, the principal manufacturers of lubricating oil agreeing to pay a royalty for the right to use superheated steam in their preparation, and by that or other methods a great change for the better was made. The volatile and dangerous oils do not now appear to be upon the market, or, at any rate, are apparently no longer offered to members of our company to any extent. They are very easily detected and avoided; and we still stand ready to examine any and all samples, and to inform all our members of the names of dangerous oils, and to warn them against the vendors.

Very soon after the change in the process of manufacture a sharp competition ensued in the sale of good oil, and a considerable reduction of prices followed.

The change in practice has been very great during the last two years. We have lately called upon the same mills that gave us data in 1878 to make a similar return for six or twelve months ending in 1880, and have received answers from 78.

From the 78 returns we get the following results:

The product of cotton goods in these mills for a period averaging $8\frac{1}{3}$ months prior to June 30, 1878, was 102,874,748 pounds, or 12,653,720 pounds per month. For a period averaging $8\frac{2}{3}$ months prior to June 30, 1880, it was 110,166,595 pounds, or 13,550,620 pounds per month. Increase in product, 7.09 per cent. The quantity of oil used in the first period was 176,766 gallons, or 1.72 gallons to each 10,000 pounds cloth. In the second period, 173,481 gallons, or 1.57 gallons to each 10,000 pounds cloth. Decrease in the consumption of oil, 8.72 per cent. The cost of oil and grease for lubrication in the first period was $103,162 25, or $10 03 to each 10,000 pounds cloth. In the second period, $73,482 71, or $6 67 to each 10,000 pounds cloth. Decrease in the cost of lubrication, 33 per cent.

If the cost of lubrication had been $10 03 for each 10,000 pounds in 1880, the gross sum would have been	$110,497 19
The actual cost was	73,482 71
Difference for $8\frac{1}{3}$ months	37,014 48
or, for 12 months, in round figures	55,000 00

The above seventy-eight mills represent an annual consumption of 400,000 bales of cotton, which constitutes about 30 per cent. of the consumption of the cotton factories insured in this or in other mutual companies. If the decrease of cost in these mills represents an average of the whole, the lubrication of machinery in cotton-mills insured by us costs $180,000 less annually than it did at the time this investigation was entered upon. The change has been computed first on fifty-three, then on sixty-five, and last on seventy-eight mills, with substantially uniform results. We may therefore infer a general rule.

Of course we cannot claim all this saving as the direct result of our work, because there has been a great decline in the prices of oils, ranging from 10 to 40 per cent., except so far as that reduction may be attributed to this investigation. One of the largest dealers to whom these figures have been submitted attributes two-fifths to the reduction of price, and the remainder to the saving of waste and to the more general use of a uniform quality of fine mineral, or so-called paraffine oil, at a substantially uniform range of prices, in place of a considerable use of mixed oils under fancy names, and at all sorts of prices. In comparing particular cases, we find this view confirmed; but, if we may not assume so much of the savings as would amount to three-fifths, or $100,000 a year, yet we may fairly claim, as the direct result of changes made in consequence of this investigation, a sum equal to all the losses and expenses of this company for the two years that have elapsed since our work began to have an influence, especially an influence on the manufacture of oil.

Section 9.—DETERMINATION OF THE VALUE OF LUBRICATING OILS BY MECHANICAL TESTS.

During the discussion that followed the lecture given by Professor Ordway, previously quoted, Mr. Edward Atkinson remarked as follows:

I will now say, also, that inasmuch as we have obtained three frictional machines—two American and one English—all of which may prove unsuitable, it has occurred to us to establish the rule of lubricating power on spinning-frames actually in operation by the application of thermometers to every spindle. * * * Three small frames have been provided, which are to be started and operated with full bobbins, and with thermometers applied to the steps and bolsters; we will then use the different oils upon them, and see if we can establish by the ratio of heat evolved any rule as to the lubricating power of each oil. In a rough-and-ready way we have applied that test to the shaft of the elevator in our office building, and there are several results that have been obtained that prove that there is a very simple method available to almost anybody. I caused some thermometers to be prepared, and mounted them in copper cartridges filled with water, and then had the journal-box of the shaft bored, and one of these thermometers placed so as to rest against the shaft as it is in use, and then hung another one in precisely the same way alongside.

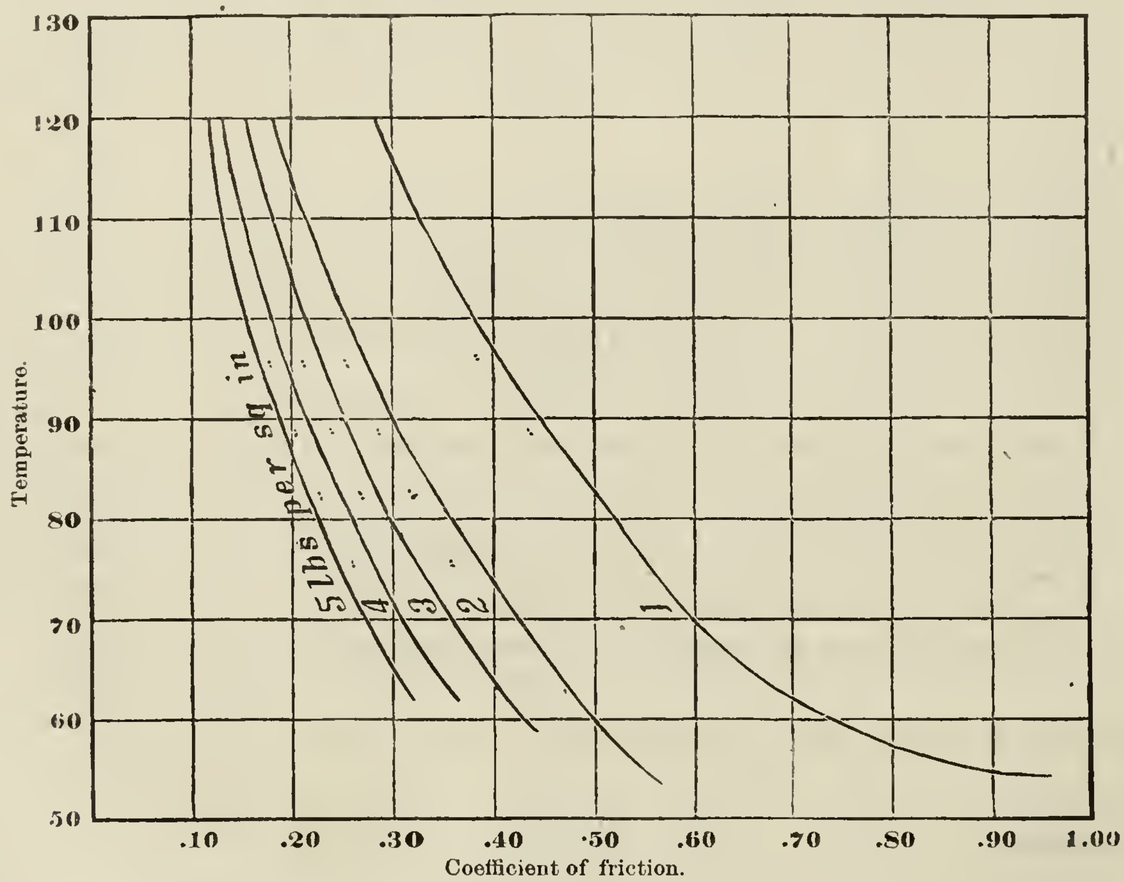
The first shaft that we tried was belted both ways, and had no serious bearing upon its journal. The second shaft is the principal shaft operating about four hundred turns, and working the elevator with the belt bearing down upon it. Under the first oil we tried the shaft heated about 30° F. In hot days, when the atmosphere of that room was at 100°, the shaft showed 128° to 130°. We then tried some light spindle oil which we didn't think fit for a heavy-bearing oil, yet that carried the heat down about 10°. We then tried some plumbago mixed with paraffine by Mr. Toppan; it was very difficult to get it on, but that worked it 10° cooler than the first oil. We then tried another oil, which heated so rapidly that we took it off at once; we didn't dare to run it. We then tried another and got down to 17° above the temperature of the room. It is a very simple matter; * * * and I think it will prove a good way for testing oils on a bad bearing, which almost every man has somewhere in his mill.

The management of the further mechanical tests was placed in the hands of Mr. C. J. H. Woodbury, of Boston, who embodied his results in a paper read before the annual meetings of the American Society of Mechanical Engineers and the American Association for the Advancement of Science for 1880. The following abstract of this paper, which presents results which "have been accepted as a long step in advance of anything ever attained before", is introduced here with the permission of the author: (*a*)

The resistance existing between bodies of fixed matter, moving with different velocities or directions, presents itself in the form of a passive force, which results in the diminution or the destruction of apparent motion. Modern science has demonstrated that this destruction is only apparent, being merely the conversion of the force of the moving body into the oscillation of the resisting obstacle, or into that molecular vibration which is recognized as heat. Direct friction refers to the case where the two bodies are in actual contact, and mediate friction where a film of lubricant is interposed between the surfaces, and it is this which applies to nearly every motion in mechanics where bodies slide upon each other. The coefficient of friction is the relation which the pressure upon moving surfaces bears to resistance. * * * In this report of my work upon the measurement of friction of lubricating oils I shall restrict myself to a description of the apparatus designed especially for the purpose, the method of its use, and the results obtained with a number of oils in our market which are used for lubricating spindles. Previous trials of nine different oil-testing machines in use showed that none of them could yield consistent duplicate results in furnishing the coefficient of friction. The operation of these machines, by their failure to obtain correct data, adduced certain negative evidence, which established positive conditions as indispensable in the construction of a machine capable of measuring the friction of oils. The following circumstances must be known or preserved constant: Temperature, velocity, pressure, area of the frictional surfaces, thickness of the film of oil between the surfaces, and the mechanical effect of the friction. In addition to the foregoing conditions, the radiation of the heat generated by friction must be reduced to a minimum, and the arrangement of the frictional surfaces must be of such a nature that no oil can escape until subjected to attrition. To measure the frictional resistance at the instant of a given temperature, and at a time when both temperature and friction are varying, requires a dynamometer which is instantaneous and automatic in its action.

The apparatus consists of an iron frame supporting an upright shaft, surmounted by an annular disc made of hardened tool steel. Upon the steel disc rests one of hard bronze (composed of the following alloy: copper thirty-two parts, lead two parts, tin two parts, zinc one part) in the form of a cylindrical box. Water is fed in at one side, and a diaphragm extending nearly across the interior produces a uniform circulation before discharge. Although this use of water is original with the writer in the method of its application, its first employment to control the temperature of the bearing surfaces of oil-testing machines is due to Monsieur G. Adolphus Hirn, and is described

DIAGRAM 1.—COEFFICIENT OF FRICTION AT DIFFERENT PRESSURES.



by him in a paper on the subject of friction, read before the Société Industrielle de Mulhouse, June 28, 1854. M. Hirn, however, confined his attention chiefly to the determination of the mechanical equivalent of heat, as measured by the amount of heat imparted to the circulating water, expressed in the work of friction. His investigations of lubrication with this apparatus were confined to the friction of lard and olive oils at the light pressure of about $1\frac{1}{10}$ pounds to the square inch. Mr. Charles N. Waite, of Manchester, New Hampshire, has independently, and I believe originally, made use of water in a friction machine, and has performed good work in the limit of his experiments.

A protection of wool batting and flannel, to guard the discs against loss of heat by radiation, diminishes the escape of heat to about two degrees per hour, which loss is not appreciable when observations are taken within a few seconds' interval. A thin copper tube, closed at the lower end, reaching through the cover, extends to the bottom of the disc; the bulb of a thermometer is inserted in this tube, and measures the temperature of the discs; an oil tube runs to the center of the disc, and a glass tube at the upper end indicates the supply and its rate of consumption, and also serves to maintain a uniform head of oil fed to the bearing surfaces. The rubbing surfaces of both discs were made to coincide with the standard surface plates in the physical laboratory of the Institute of Technology (Boston, Massachusetts), and their contact with each other is considered perfect.

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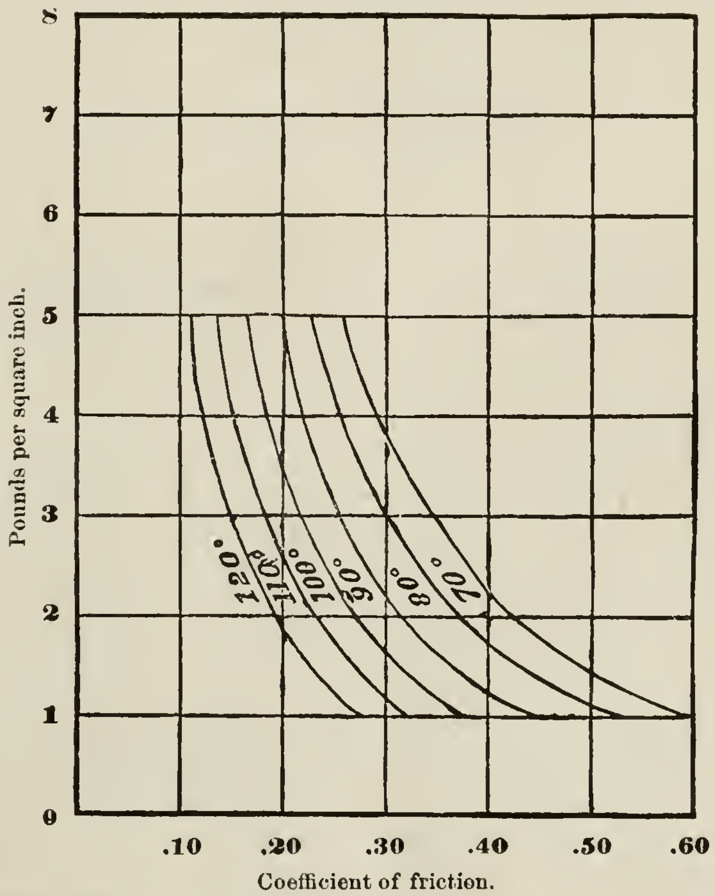
a The tables which accompany this paper are not introduced here. They may be found in the proceedings of the American Association for the Advancement of Science for 1880, pages 197–221.

After this surface was finished the bronze disc was treated with bichloride of platinum, which deposited a thin film of platinum upon the surface. Upon the application of the discs to each other the steel disc rubbed off the platinum from all parts of the surface, showing the perfection of contact. This nicety of construction enables a film of oil of uniform thickness to exist between the surfaces, and the resistances are not vitiated by the collision of projecting portions of the disc with each other. The rounded end of the upper shaft fits into a corresponding depression in the top of the upper disc. This method of connection retains the disc over the proper center, yet it is allowed to sway enough to correct any irregularity of motion caused by imperfection of construction or wear of the lower disc. To obtain the desired condition of pressure, weights are placed directly upon the upper spindle. The axes of the upper and lower spindles do not lie in the same straight line, but are parallel, being about one-eighth of an inch out of line with each other. Such construction, giving a discoid motion, prevents the disc from wearing in rings and assists in the uniform distribution of the oil. An arm is keyed through the lower part of the upper spindle and engages with projections upon the upper disc. Upon this arm, which is turned to the arc of a circle, whose development is two and one-half feet, a thin brass wire is wrapped and reaches to the dynamometer, so that the tension of the dynamometer is tangential and the leverage is constant for all positions of the upper disc within its range of motion. The dynamometer consists of a simple bar of spring steel fastened at one end and bent by the pull applied at the other. Its deflection is indicated by a pointer upon a circular dial, the motion of the spring being multiplied about eighty times by a segment and pinion. The whole is inclosed in a steam-gauge case.

When completed, the machine was subjected to a long series of tests with the same oil, to determine the accuracy of the results and the best method of procuring them. The operation of the machine under equal conditions with the same oil gives results which are as closely consistent with each other as could be expected from such physical measurements. As an example, four tests of the Downer Oil Company Light Spindle at 100° F., and on different days, gave 0.1145, 0.1094, 0.1118, 0.1094: mean, 0.1113. * * * Much of the irregularity, slight as it is, is due to the variable speed of the engine. Concurrent results were obtained under equal circumstances, but the coefficient of friction varied, not merely with the lubricants used, but also with the temperature, pressure, and velocity. The results of my own experiments on mediate friction do not agree with the laws of friction as given in works on mechanics, but the coefficient of friction varies in an inverse ratio with the pressure, as shown graphically in the diagram (page 204).

These curves belong to the hyperbolic class of a high degree; but I have not been able to deduce an equation which will answer to the conditions of more than one, because the law of the curves is modified by a constant, dependent upon the individual sample of oil used. A little difference in the sample would cause a difference in the line of curve. Reference is made to diagram 2, showing the coefficient of friction under equal ranges of temperature and velocity, but with a different series of pressures.

DIAGRAM 2.—CURVES SHOWING CHANGES OF COEFFICIENT OF FRICTION UNDER VARYING CONDITIONS.



Coefficient of friction at 100° and 500 revolutions per minute:

Pressure per square inch.	Coefficient of friction.
1 pound	0.3818
2 pounds	0.2686
3 pounds	0.2171
4 pounds	0.1849
5 pounds	0.1743

The ratio of the changing coefficient varies with the temperature at which the range of results is taken.

Friction varies with the area, because the adhesiveness of the lubricant is proportional to the area, and the resistance due to this cause is a larger fraction of the total mechanical effect with light than it is with heavy pressures.

The limit of pressure permitting free lubrication varies with the conditions; for constant pressures and slow motion it is believed to be about 500 pounds per square inch, while for intermittent pressures, like the wrist-pin of a locomotive, the pressure amounts to 3,000 pounds per square inch. It has been stated that about 4,000-foot pounds of frictional resistance per square inch is the maximum limit of safe friction under ordinary circumstances.

As the results of this preliminary work indicated that the coefficient of friction varied with all the circumstances, it was necessary to simulate the conditions of specific practical applications to determine the value of a lubricant for such purposes.

It was decided to begin these investigations with spindle oils, and therefore the machine was loaded with 5 pounds to the square inch and run at about 500 revolutions per minute, as the oil is then submitted to conditions of attrition corresponding to those met with in extremes of velocity and pressure, in the case of a Sawyer spindle running at 7,600 revolutions per minute, with a band tension of 4 pounds, and the results subsequently given refer only to the friction under these conditions, except when definitely stated to the contrary.

This particular spindle was selected because, of the 5,000,000 ring spindles in the United States, about 1,500,000 are of this manufacture, and in a large number of the remainder the conditions of lubrication are quite similar.

In a Sawyer spindle the step measures $\frac{3}{8}$ by $\frac{15}{100}$ inch, and receives $\frac{7}{8}$ of the pull due to the band. If that tension is 4 pounds, $3\frac{1}{2}$ pounds are transmitted to the step, whose projected area is $\frac{9}{16}$ square inch. The pressure per square inch is, therefore, $5\frac{1}{3}$ (say 5) pounds.

The diameter of the spindle at bolster is 0.28″, or 0.8976″ in circumference. At 7,600 revolutions per minute its velocity amounts to 6,685″, or 557 feet, per minute; and the mean area of the discs of the oil machine must revolve at this speed.

To illustrate, let—

R = outer radius of disc = 2.656 inches.
r = inner radius of disc = 1.435 inches.
n = radius of circle bisecting the area.

$$\text{Fractional area of annular disc} = \pi(R^2 - r^2) \qquad (1)$$
$$\text{area of outer half} = \pi(R^2 - n^2) \qquad (2)$$
$$2\pi(R^2 - n^2) = \pi(R^2 - r^2) \qquad (3)$$
$$2\pi R^2 - 2\pi n^2 = \pi R^2 - \pi r^2 \qquad (4)$$
$$2R^2 - 2n^2 = R^2 - r^2 \qquad (5)$$
$$-2n^2 = -R^2 - r^2 \qquad (6)$$
$$2n^2 = R^2 + r^2 \qquad (7)$$
$$n^2 = \frac{R^2 + r^2}{2} \qquad (8)$$
$$n = \sqrt{\frac{R^2 + r^2}{2}} \qquad (9)$$
$$\text{Length of line bisecting the area} = 2\pi n = \sqrt{\frac{4\pi^2(R^2+r^2)}{2}} \qquad (10)$$
$$= \sqrt{2\pi^2(R^2+r^2)} \qquad (11)$$
$$= \sqrt{2 \times 9.87(7.05+2.11)} \qquad (12)$$
$$= \sqrt{19.74 \times 9.16} \qquad (13)$$
$$= \sqrt{180.8184} \qquad (14)$$
$$= 13.45 \text{ inches.}$$
$$= 1.12 \text{ feet.}$$

To give a desired fractional velocity of 6.685 inches per minute the discs must revolve at 6,685 divided by 13.45 = 497 (say) 500 revolutions per minute. To recapitulate: By revolving the disc at 500 revolutions per minute, with a pressure of 5 pounds per square inch, the oil is submitted to conditions of attrition corresponding to those in the extremes of velocity and pressure met with in a Sawyer spindle revolving at 7,600 revolutions with a band tension of 4 pounds.

My reason for giving such a detailed statement is, because the value of investigations upon this subject must be measured by the precision with which all the conditions are observed.

The apparatus is used in the following manner to measure the coefficient of friction of oil: After cleaning with gasoline and wiping carefully with wash leather, the discs are oiled and run for about five hours, being kept cool by a stream of water circulating through the upper disc. From time to time they are taken apart, cleaned, and oiled again. After using any oil, even if the discs are afterward cleaned, the results with the oil subsequently used give the characteristics of the previous oil, and it is only after thirty-five to forty-five miles of attrition that these results become consistent with each other, each succeeding result, meantime, approaching the final series. This seems to indicate that friction exists at the surface of the two discs, between the film of oil acting as a washer and the globules of oil partially embedded within the pores of the metal. If the dense bronze and steel retain the oil despite attempts to remove it, how much longer must it require to replace the oil in machinery with a new variety whose merits are to be tested? These experiments confirm the wisdom of the increasing use of cast-iron for journals, as its porosity enables it to contain and distribute the lubricant.

When the discs are ready to test the oil the apparatus is cooled by the circulation of water, the flow of which is stopped when the machine is started. At every degree of temperature the corresponding resistance is read on the dynamometer. When the thermometer indicates a temperature of sixty degrees, the counter is thrown in gear and the time noted. When one hundred and thirty degrees is reached, the counter is thrown out of gear and the time noted. This not only gives the velocity of the rubbing surfaces, but the number of revolutions required to raise the temperature a stated number of degrees, and is a close criterion of the oil. The coefficient of friction is the ratio of the pressure to the resistance, and is deduced in the following manner:

P = Weight on discs.
R = Outer radius of frictional contact.
r = Inner radius of frictional contract.
N = Number of revolutions per minute.
W = Reading on dynamómeter.
φ = Coefficient of friction.

In the friction of annular discs the portions of the surface near the perimeter have a greater leverage than those near the center. The mean sum of these moments is found by the calculus.

Let e be the radius of any infinitesimal narrow ring or band. Then will—

Width of band $= de$ . . . . (1)

Length of band $= 2\pi e$ . . . . (2)

Area of band $= 2\pi e de$ . . . . (3)

Moment of band $= 2\pi e^2 de$ . . . . (4)

The expression for the area of an annular disc is $\pi(R^2-r^2)$ . . . . (5)

To express the moment of a ring in terms of an annular surface, divide Eq. 4 by Eq. 5, as follows:

$$\frac{2\pi e^2 de}{\pi(R^2-r^2)} = \frac{2e^2 de}{R^2-r^2} = \frac{2}{R^2-r^2} e^2 de = \text{Moment in terms of disc} \qquad (6)$$

$$\text{Moment of whole disc} = \frac{2}{R^2-r^2} \int e^2 de \qquad (7)$$

$$\text{Integration of whole disc } \frac{2}{R^2-r^2} \left\{ \frac{e^3}{3} \right\}_r^R \qquad (8)$$

$$\text{Substituting the limits } R^2-r^2, \frac{R^3-r^3}{3} \qquad (9)$$

$$\text{and calling the work of friction} = \varphi P \qquad (10)$$

$$\text{Statical moment of friction of disc} = \frac{2\varphi P(R^3-r^3)}{3(R^2-r^2)} \qquad (11)$$

$$\text{Mechanical effect} = \frac{4\pi\varphi P(R^3-r^3)}{3(R^2-r^2)} \qquad (12)$$

$$\text{Foot pounds at any velocity} = \frac{4\pi\varphi P(R^3-r^3)N}{3(R^2-r^2} \qquad (13)$$

As previously stated, the dynamometer exerts a pull at the end of a lever whose development is $2\frac{1}{2}$ feet.

$$\text{Resistance of dynamometer} = \frac{5W}{2} \qquad (14)$$

$$\text{Resistance of dynamometer in foot pounds at any velocity} = \frac{5WN}{2} \qquad (15)$$

Then as the total friction = the resistance of the dynamometer,

$$\text{Eq. } 13 = \text{Eq. } 15$$

$$i.\ e.,\quad \frac{4\pi\varphi PN(R^3-r^3)}{3\ (R^2-r^2)} = \frac{5WN}{2}$$

Simplifying we have

$$8\pi\varphi PN(R^3-r^3) = 15WN(R^2-r^2) \qquad (16)$$

$$8\pi\varphi P\ (R^3-r^3) = 15W\ (R^2-r^2) \qquad (17)$$

$$\varphi = \frac{15W(R^2-r^2)}{8\pi P(R^3-r^3)} \qquad (18)$$

$$\text{Separating the constants, } \varphi = \frac{15(R^2-r^2)W}{8\pi(R^3-r^3)P} \qquad (19)$$

and $R = 0.2214$ feet

$r = 0.1211$ "

$R^3 = 0.01083$	$R^2 = 0.0489$
$r^3 = 0.00177$	$r^2 = 0.0146$
$R^3 - r^3 = 0.00906$, log. 7.9571282	$R^2 - r^2 = 0.0343$, log. 8.5352491
$\pi = 3.1416$, log. 0.4971499	(R^2-r^2) log. 8.5352491
8 " 0.9030900	15 log. 1.1760913
9.3573681	9.7113404
9.7113404	
0.3539723 = 2.259	

$$\varphi = \frac{2.259W}{P} \qquad (20)$$

This equation was solved for each reading of the dynamometer with five pounds pressure on the square inch, and the results tabulated in a convenient form for computing the coefficient of friction from the observed results.

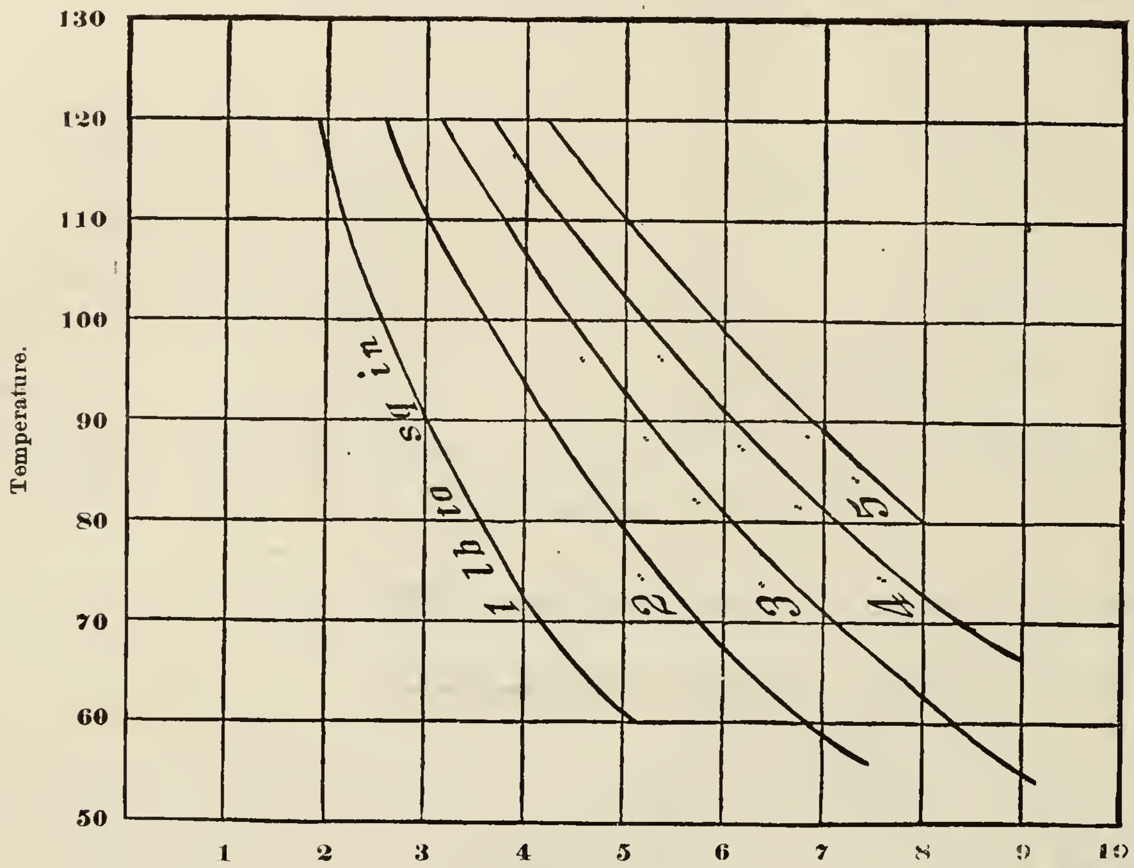
The table on page 208 shows the resistance of friction at 100°, 500 revolutions, for various pressures.

RESISTANCE OF FRICTION AT 100°.

Pressure pounds.	Resistance on dynamometer. Pounds.	Equivalent band tension.
1	2.62	0.8
2	3.68	1.6
3	4.48	2.4
4	5.28	3.2
5	5.98	4.0

For further detailed results, reference is made to diagram 3.

DIAGRAM 3.—RESISTANCE OF FRICTION AT DIFFERENT PRESSURES.



These results seem to be intimately relevant to the most desirable limit of tension to the spindle-band methods of operating cotton-spinning machinery. By weighing the band tension in various mills it was found that the practice of tying bands lacked uniformity. As an example of this variation: in one mill the bands of a single coarse frame are reported to vary from 1 to 16 pounds. In another mill, on finer work, a number of spindles had a range of from ½ to 2½ pounds, and in a third mill the band tension was between the limits of ¼ to 5 pounds. The effect of atmospheric changes upon the fiber of textile bands renders it impossible, with the present method of constructing frames, to keep them at a uniform tension, but this variation can be reduced by a little care. Is it not worth while for each spinner to learn the proper band tension required for his special work, and then keep within those limits? The whole power required to run the frame would not vary in direct proportion to the varying resistance due to the friction of spindles at various pressures, because the resistance of the friction in other parts of the frame connected with the spindles, the actual spinning of cotton fibers, and the alternate contraction and expansion of the bands, are conditions which are more nearly constant, and in no case do they vary in proportion with the friction of the spindle, yet the variation is large, as shown by the following experiment made with the frame:

Mr. George Draper, in a communication to the *Industrial Record* of June 1, 1879, gives the following valuable data on this subject: A frame of Sawyer spindles was taken spinning No. 30 yarn, ordinary twist, the front rolls running 95 revolutions per minute. The rings were of 1⅝ inches diameter, and the traverse of the yarn on the bobbins 5½ inches. The dynamometer was applied, and the power required to drive the spindles, with a side pull of the bands averaging 2 pounds to a spindle, was ascertained. The bands were then cut and a new set put on with a side pull of 3 pounds per spindle, and the frame tested again, all things remaining as before. The operation was then repeated at 4, 5, 6, 7, 8, and 9 pounds side pull per spindle, with the result shown in the following table.

Calling the amount of power required to drive the spinning frame with—

2 pounds tension on the bands	= 100
3 pounds tension on the bands	= 117
4 pounds tension on the bands	= 131
5 pounds tension on the bands	= 144
6 pounds tension on the bands	= 159
7 pounds tension on the bands	= 177
8 pounds tension on the bands	= 197
9 pounds tension, considerably more than double.	

The lubricant used is one of the most important factors in the cost of power. In the present condition of engineering science it is impossible to state what exact proportion of the power used by a mill is lost in sliding friction, but in a print-cloth mill only about 25 per cent. of the power is utilized in the actual processes of carding, spinning, and weaving the fiber, not including the machinery engaged in the operation, leaving 75 per cent. of the power as absorbed by the rigidity of belts, the resistance of the air, and friction. The coefficient of friction, under the conditions submitted by my oil-tester, varies, at 100°, 500 revolutions from 7.56 per

cent. in the case of 32° Ex. machinery oil manufactured by the Downer Oil Company, to 24.27 per cent. in the case of neats'-foot oil; and the result of this investigation confirms me in the opinion that the successful operation of a spinning frame is far more closely dependent upon the individual management in respect to the conditions of band tension, lubrication, and temperature of the spinning-room than all other causes combined. Not that some forms of spindle are not superior to others, but that, without wise supervision, the most desirable forms of spindle must fail to show the merits due to the skill of their promoters. It may be stated that, within a close approximation, the lubricating qualities of an oil are inversely proportional to its viscosity; that is, the friction decreases with the cohesion of the globules of the oil for each other. The endurance of a lubricant is in some degree proportional to its adhesion to the surfaces forming the journal. An ideal lubricant in these respects would be a fluid whose molecules had a minimum cohesion for each other and a maximum adhesion for metallic surfaces. The viscous oils will also adhere more strongly to metals, and hence, under the conditions of heavy bearings, it is obligatory to use such thick lubricants, knowing that the employment of an oil with great frictional resistance is infinitely preferable to the attempt to use an oil so limpid that it could not be retained between the bearings. With light pressures the more fluid oils are admissible, and in all cases the oils should be as limpid as the circumstances will permit. Oils with great endurance are apt to give great frictional resistance, and in the endeavor to save *gallons* of oil many a manager has wasted *tons* of coal. The true solution of solving the problem of lubricating the machinery of an establishment is to ascertain the consumption of oil and the expenditure of power, both being measured by the same unit, viz, dollars.

The fluidity of the oils was measured by the following apparatus: A pipette was placed within a glass water-jacket, where the temperature was controlled and kept constant by circulation from a reservoir kept at the desired temperature. The capacity of the bulb is twenty-eight cubic centimeters and the orifice measures three and a half inches long and 0.039 of an inch in diameter.

The oil was drawn into the bulb of the pipette, and after the whole was brought to the desired temperature the time required for its discharge was accurately noted by a stop watch.

These observations were made on each of the oils for a series of temperatures varying from 50° to 150° F.

If the fluidity of an oil is the measure of its lubricating qualities, these observations would not be identical with the frictional results, because the pressure in this case was that due to a head of about five inches of oil, or about one-sixth of a pound to the square inch and rubbing against a glass surface; while with the frictional machine the pressure was five pounds to the square inch, and the surfaces bronze and steel.

In both cases, however, the character of the surfaces and the pressures were uniform conditions, and therefore they would not affect the relations of either set of experiments in their consistency with each other. If the lubrication and fluidity of oils followed the same law of variation with the temperature, the results of one would be directly proportional to those in the other, provided that all other conditions were preserved constant. Such comparisons showed that the relations of the fluidity to the lubricating qualities did not follow any uniform ratio.

At a low rate of temperatures the fluidity increased faster than the lubricating quality of the oil; between about 70° and 110° the coincidence was quite close; at higher temperatures the fluidity does not increase so fast as the lubrication. There was not a very close correspondence between the fluidity of oils at the same coefficient of friction.

The result of these investigations upon the relation of fluidity to lubrication seems to indicate that fluidity is a concomitant rather than a cause of the anti-frictional qualities of a lubricant.

In the case of mining drills operated by condensed air, an intense cold is produced at the liberation of air, and on some such bearings kerosene oil is the only lubricant which can be used. I think it extremely probable that at these low temperatures the viscosity of kerosene oil is equal to that of lubricating oils at the average temperature of bearings in general use. On the other hand, only the most viscous oils can be used in such extremely high temperatures as the cylinder and steam-chest of steam-engines.

According to the results which I have obtained, the coefficient of friction at 50° is about 75 per cent. in excess of that at 75°, and it seems to me that the manager of every mill which is run by steam ought to consider the question of the temperature of the mill in early morning during the winter months, whether, as a matter of economy, it is cheaper to warm a mill by increased friction on Monday morning, or to keep the mill and machinery warm during the interval from the preceding week.

The humidity of the atmosphere is an important factor in the mechanical operation of textile machinery, as well as in the fabrication of cotton. A year ago I submitted to the New England Cotton Manufacturers' Association measurements showing the effects of humidity on textile bands, and I am also of the opinion that there is a difference of friction in machinery due to atmospheric influences upon the lubricant.

Possibly the moisture condensed upon the cold metal from the atmosphere becomes commingled with the oil and thereby reduces its viscosity, diminishing the friction.

The question of endurance of oils has not been given in these experiments, because the consumption of oil varies with the temperature, and it is proposed to investigate the matter subsequently by running the machine and controlling the temperature of the discs to 100° by the circulation of water. The amount of oil consumed could be very easily measured by the difference in the level of the glass feeding-tube or the weight of the oil required to preserve it at that level during the experiment.

In the detailed results the friction is given for the whole range of temperatures, but in the following summary 100° has been selected as the temperature which most nearly corresponds to the heat of spindle bearings.

To ascertain these temperatures, holes were drilled in the rails of a spinning frame, passing as near the bolsters and steps as possible; the bulbs of thermometers were inserted in these holes, and while the frame was in operation 2,586 readings were taken, covering a period of four weeks. The temperature of the air was noted from a thermometer placed in the middle of the frame.

The mean temperature of the bolsters was 8.10° F., and of the steps 6.74° F., above the temperature of the room.

Other experiments were made to learn the temperature of the bearings of the shafting. Holes about half an inch in diameter were bored in the upper cap of such journals, and a thin copper tube, closed at the lower end, inserted and extended nearly to the shaft. This tube contained water, and the temperature was measured by a thermometer placed therein. The temperature of the room was measured by a thermometer hung near the bearing. There were journals in good running order whose temperature at the frictional surfaces was 140° F. This method of using thermometers was first suggested by Mr. Edward Atkinson, and I consider it the most accurate test of the anti-frictional qualities of a lubricant at the service of those in charge of machinery.

Great pains have been taken to procure pure samples of the oils experimented with, and they were obtained directly from the manufacturers; and to the courtesy of Mr. Thomas Bennett, jr., I am indebted for a large number of samples of sperm oils which were procured by him directly from the whale-ships or refiners.

The following table gives the coefficient of friction at 100° F. and 500 revolutions, with a pressure of 5 pounds to the square inch:

No. of sample.	Kind of oil.	Coefficient of friction at 100°.	No. of sample.	Kind of oil.	Coefficient of friction at 100°.
1	Mineral oil	0. 1635	100	Mineral oil	0. 1309
28	Mineral oil	0. 1732	3	Lard	0. 2181
10	Mineral oil	0. 1187	4	Bleached winter sperm A	0. 1067
14	Mineral oil	0. 1233	5	Bleached winter sperm B	0. 1217
19	Mineral oil	0. 1208	6	Bleached winter sperm C	0. 1170
7	Mineral oil	0. 1113	9	Bleached winter sperm D	0. 0956
20	Mineral oil	0. 1132	18	Bleached winter sperm E	0. 1141
8	Mineral oil	0. 0756	17	Unbleached winter sperm	0. 1147
2	Mineral oil	0. 1476	21	Seal oil	0. 1608
11	Mineral oil	0. 1493	22	Neat's-foot	0. 2427
12	Mineral oil	0. 1201	23	Mixed animal and mineral oil	0. 1608
15	Mineral oil	0. 2243	24	Mixed animal and mineral oil	0. 1377
95	Mineral oil	0. 0973	25	Mixed animal and mineral oil	0. 1190
96	Mineral oil	0. 0950	90	Paraffine	0. 1247
13	Mineral oil	0. 1190	92	Paraffine mixed with one-fifth sperm	0. 1185
16	Mineral oil	0. 1103	93	Paraffine mixed with one-third neat's-foot	0. 1347
91	Mineral oil	0. 1360	94	Unknown sperm	0. 1397
98	Mineral oil	0. 1189			

Chemical examinations of these oils by Mrs. Ellen H. Richards, of the Women's Laboratory, Institute of Technology:

No. of sample.	Flash of vapor.	Loss of evaporation in 12 hours at 140° F.	Nitro-sulphuric acid test.
	Degrees.	*Per cent.*	
10	338	1. 3	Dark yellow, with much cake.
7	314	2. 7	Dark yellow, some cake.
8	284	5. 5	Slightly yellow, only a few flakes of cake.
2	316	3. 7	Dark yellow, thin layer of cake.
11	324	3. 9	Slightly yellow, not on brown specks.
12	318	3. 3	Yellow, not a single flake, no solid matter.
15	286	7. 2	Turned dark, gives a black layer of gum.
13	322	1. 9	Quite an amount of cake.
16	282	5. 0	Do.
3	....	+0. 4	Hardened with much acid to a white solid mass.
9	....	+0. 3	Thickened up a little, like jelly.

With castor oil the friction was so great as to throw off the belt driving the machine; and as the time alloted for this work expired on that day, other arrangements for a wider belt could not be made, and it can only be said that its friction exceeds that of any other oil given in these tables. * * *

The anti-frictional properties of these oils under the conditions of these experiments are expressed in the following order:

No. of sample.	Kind of oil.	Coefficient of friction at 100°.
8	Mineral	0. 0756
9	Bleached winter sperm	0. 0956
16	Mineral	0. 1103
7	Mineral	0. 1113
18	Bleached sperm	0. 1141
17	Unbleached sperm	0. 1147
13	Mineral	0. 1190
12	Mineral	0. 1201
19	Mineral	0. 1208
2	Mineral	0. 1476
21	Seal	0. 1608
28	Mineral	0. 1732
3	Lard	0. 2181
15	Mineral	0. 2243
22	Neat's-foot	0. 2427

It is no disparagement to the qualities of an oil that it is low in the foregoing list, except so far as it relates to the resistance of friction under these conditions. For circumstances of great pressure and slow motion, I am of the opinion that the order of the list would be varied; and if the question of endurance were only to be considered, still another change in the order would be necessary.

A portion of a lot of unbleached sperm oil (sample 17) was bleached expressly for these tests (sample 18), but the results of the two are so nearly uniform as to be practically identical. The result of bleaching does not affect the anti-frictional properties of the oil, although it undoubtedly reduces its gumming qualities. The friction of sperm oil is subject to sudden variations, which occur at

certain temperatures for the same sample of oil. The explanation of this lies in the fact that sperm oil consists of a large number of varieties of spermaceti, each of which is liquefied at certain temperatures, at which the oil is relieved of waxy, or at least gelatinous particles, and becomes a more perfect lubricant. * * *

The friction of lard oil for high temperatures exceeds that of any other lubricant in the list; and this adhesive quality enables it to remain on tools used for cutting iron.

In conclusion, it may be stated that the data necessary to determine the safety and efficiency of a lubricant comprise:

1. The flashing point of its vapor, which is ascertained by slowly heating a sample over an oil bath, quickly passing a small flame over the oil and noting the temperature at which the vapor first flashes. The danger from an oil does not arise from the point at which the oil actually ignites, but at the lower temperature, when the inflammable vapor bursts into flames, which communicate fire to a distance limited only by the extent of the vapor.

2. The quantity of such volatile matter is important both as respects safety and value. The heat of friction liberates that portion of the oil which is volatile at the temperature of the bearings, filling the mill with a dangerous noxious vapor, and also dissipates in the air a portion of the oil which is paid for by the gallon, but does not serve to give any return of value in lubrication. The quantity of matter volatile under 140° F. is measured by heating a known weight of oil in a watch-glass and maintaining a constant temperature of 140° F. for 12 hours. This simulates the conditions of the temperature of the bearings mentioned previously and the maximum time that it would be consecutively heated. In the case of mineral oils the loss from evaporation varied from less than 1 up to 30 per cent. With animal and vegetable oils there is a slight gain in weight, due to oxidation.

3. The tendency to spontaneous combustion is estimated by a uniform amount of cotton-waste smeared with a certain quantity of oil. A thermometer whose bulb extends to the center of the mass indicates any rise of temperature due to oxidation. Any gain of weight during the preceding evaporation test shows a liability to spontaneous ignition.

4. Freedom from acid is an important factor in oil, because acid is a cause of corrosion of metals, and will tend to remove the oil from the frictional surfaces when adhesion is indispensable. The presence of acids is shown by corrosion of copper.

5. The anti-frictional properties of an oil can be measured only by direct trial under the desired conditions of pressure, velocity, and temperature. The results of these experiments show that a lubricant must have a certain adhesion to the frictional surfaces to maintain free lubrication, but beyond that point the adhesiveness of the oil resists the motion of the surfaces, increasing the friction. A thick oil gives greater frictional resistance than a thin one; and when ease in running is the object the most limpid oil should be used consistent with the specific circumstances of the bearing. In general terms, the specific gravity of an oil gives no indications of its value as a lubricant in qualities of viscosity, body, or endurance. * * *

When this paper was read at the meeting of the American Society of Mechanical Engineers, Professor R. H. Thurston spoke as follows:

Mr. Woodbury in his paper made some reference to the fact that the coefficients of friction, as ordinarily stated, are not found to be strictly correct; in other words, that there are no such losses in ordinary practice. Then he has shown you here how seriously the temperature of the lubricant affects the coefficient of friction. You will notice that the work done is all at extremely light pressures. It is simply due to the pull of the band, and the resultant of that and the resistance of the work of the spindle. It is exceedingly light, and it is for that reason that we get what appeared to be extremely high coefficients of friction. In the table exhibited you will see that the coefficients run from 7½ up to about 20 per cent., the highest figure being lard oil and a special grade of machinery oil, which are each about 22 per cent. Now, a fact which was not brought out so strongly by the paper as it might have been is, that this coefficient is also affected very largely by the pressure per square inch put upon the journal, and what I intended specially to remark upon was the fact that these coefficients do not represent the values of the coefficients obtained in ordinary engine work, but are the coefficients obtained in extremely light work, as in the spinning-frames of cotton-mills. If we use the same lubricating material, and the same surface pressure, rising above that to fifty pounds, we will find the coefficients come down in value to a fraction of the figures given on the scale. Carrying the pressure up to a very common figure, such as we might get with any machine work, of 100 or 200 pounds, we will find that the coefficient is reduced. I have had occasion to make tests of various kinds of oil between various sorts of surfaces, and, under varying pressures and temperatures, up to pressures of 1,500 pounds to the square inch, and for a very short period of time 2,000 pounds to the square inch, and at temperatures which ran from the ordinary atmospheric temperature to above the boiling point of water, and I find that upon the crank-pins of steam-engines, such as are sometimes used on the North River boats, carrying the pressure of a thousand pounds to the square inch, instead of a coefficient of friction of 5 per cent. we get one-tenth of 5 per cent.—one-half of 1 per cent. for the coefficient of friction—so that the field explored by Mr. Woodbury is limited to these extremely low temperatures. They do not represent the results as ordinarily obtained, or exceptional results obtained by putting on tremendously high pressures, so that if we take the very best of lubricating materials—sperm oil is the best I have ever found for heavy pressures—and put a pressure upon it of a thousand pounds to the square inch, then, instead of the text-book coefficients of friction, all the way from 4 to 7 per cent., we get figures that run to one-tenth of that amount. I have obtained coefficients of friction with sperm oil as low as one-fourth of 1 per cent.

The pressure, therefore, at which you are working is one of the very important elements in determining what is to be the coefficient of friction to be assumed in design.

Now, I spoke of this partly as a commentary on this paper and partly as a commentary on that of Mr. Hoadley. Mr. Hoadley shows us that we may divide the circumference described by the crank-pin by horizontal and vertical lines, and he calls the upper and lower of the two sections of his circumference the work-doing parts of the traverse of the crank-pin, and the end sections he calls the work-using sections.

Now he shows us what is the effect of friction in reducing the efficiency of engines where we put full pressure on the crank-pin at either end of the stroke; but it must be observed, as a commentary upon that statement, that these figures are very much smaller than we have been accustomed to assume. The friction of the crank-pin in a well-made engine, with a good bronze box, running on good steel journals, ought to come down to a fraction of 1 per cent. That being the case, we get the result that Mr. Porter indicated, that the loss of power at the two ends of the stroke becomes insignificant, more insignificant than I presume he had supposed.

A remark was also made by another member of the society upon our determinations of the value of lubricating oils for steam-cylinders. In a long series of experiments, which I have had occasion to make on lubricating oils to be used in steam-cylinders, I have taken oils furnished in the market for that purpose and tested them at the temperature of the steam-cylinder, bringing them up to a temperature of 250° or 300°, and some cases 350°, and I found that the value of the oil for lubricating purposes within the steam-cylinders is by no means the same as its value for lubricating on the crank-pin and other external parts not subjected to high temperatures, and that the oil giving the best results on the crank-pin may give poor results in the cylinder.

In several cases I have found that oils that were among the best for ordinary use were among the poorest for cylinder work, while other oils that were not nearly so good for external use were among the very best for use within the steam-cylinder. So no one can tell what is the value of an oil for the purpose to which he applies it until he subjects it to a test under precisely those conditions.

Mr. Woodbury presented us with the results of work done under the precise conditions of actual use. He runs the spindles at the ordinary speed, and runs them as in ordinary spinning frames, and then measures the friction, and the data he gives are of course absolutely reliable as determining the results to be met with under that set of conditions. That is one reason why we may rely so absolutely, I presume, upon his results. He has determined under these conditions what is the comparative value of a large number of oils; but I wish to renew his caution that we are not to take these results, which represent the relative value of oils for spindles, as representing the relative value of those oils for crank-pins or the lubrication of steam-cylinders. Another remark was made in the paper, apparently incidentally, that a man may save a considerable amount of money in the purchase of his oils, while losing at the same time a vastly greater amount in paying his coal bills, and that leads to the question how are we to determine the money value of these oils? It is evident that the value to the dealer is not at all likely to be just its value to the purchaser. The money value of the oil to the consumer is something less than the money value of the work that it is going to save him in friction, or the money value of the work that it is going to save him in friction added to the money value of the work it is going to save him in repairs and incidental expenses. If you will take the trouble to determine the cost of the power in any mill or machine-shop in the country, and then assume a change in the coefficient of friction from an average of, we will say, 2 or 3 per cent. to an average of 5 per cent., and see what you can afford to pay for oil that will avoid that increase of friction, you will find probably in every case in which you make the calculation that you can better afford to pay the highest prices in the market for the best oils than to take as a gift the oils which give you the highest coefficients of friction.

I took occasion some time ago to work that up in a specified case—that of Mr. Sellers' shop—I don't remember now what the figures were, but the result was such as to show that we could better pay a good many times the value of the best sperm oil in the market to reduce losses by friction than to take the cheapest oils in the market with the increase of those losses.

The difference between the lowest coefficients and the highest coefficients is about 1 to 3.

But when you are calculating the cost of the power required to overcome this friction, you will find that even slight differences are sufficient to justify you in making your estimate of costs in taking the very highest-priced oil, even if it gives you a very little decrease in the coefficient of friction.

In a circular issued near the close of the year 1880 by Mr. Atkinson, he gives a summary of the results obtained in the research conducted by Mr. Woodbury, and remarks:

Another result of this work has been the invention of the machine on which we can now ascertain the anti-frictional properties of any oil with absolute certainty, and by the use of which we have obtained measurements of the coefficient of friction with an accuracy and uniformity that have never been approached before. * * * Our machine having been adjusted in velocity and other conditions to those of a Sawyer spindle operating at 7,600 turns per minute under a band tension of 4 pounds, it appeared that the difference in power required to overcome the resistance of the parts varied as follows:

The resistance or power required to operate the frictional machine at 100° F., when lubricated with Downer Oil Co. 32 extra machinery oil, amounted to 756, and under the same conditions, with the exception of the substitution of neat's-foot oil as a lubricant, the resistance amounted to 2,427, or three and twenty one-hundredths times as much.

In respect to the same oil at different degrees of temperature in the bearing, the resistance at 50° is about 75 per cent. in excess of that at 75° F.

In respect to the best oil and poorest lubricant at 100° F., the difference is 321 per cent.

In respect to a difference of pressure varying from 1 pound to 5 pounds, the difference is 229 per cent.

By means of experiments applied to a small Sawyer spindle-frame, which could not be reduced to such precise accuracy, but which marked the great variations in power according to the greater or less tension of the bands, other results were reached of the same general character, fully confirming the above conclusions.

The general conclusions reached are, therefore, that although, as a matter of course, there must be a marked difference in power needed between a well-planned and constructed and a badly-constructed spinning-frame, yet, when it is a question between two well-constructed frames, * * * the greatest differences in details (of construction) do not make as much difference in the power required as may be made in the adjustment and tension of the bands or in the quality and condition of the oil, and hardly as much as may be made by variations in the temperature and condition of the atmosphere and of the machine, or in the quality and condition of the stock in use. The uniform tension of the band appears to be the factor of the greatest importance, and the structure of the bobbin of the least, provided the spindle is long enough and heavy or stiff enough to keep the bobbin true and to prevent it from springing under the varying conditions of the atmosphere.

In respect to the best quality of oil to be used on spindles—that is to say, the best oil to be used on light bearings at very high velocity—a few simple rules may now be laid down dogmatically, so far as rules are to be made by experiments on a single machine or from laboratory experiments.

1. A mineral oil that flashes at less than 300° F. does not possess the best qualities for lubrication, and is unsafe in proportion to the lesser degree at which it flashes.

2. A mineral oil that evaporates more than 5 per cent. in ten hours at a heat of 140° F. is hazardous in proportion to the increased percentage of volatile matter, and is also more unfit to be used as a lubricant the more rapidly it evaporates, because the remainder will either become thick and viscous, requiring a high heat in the bearing to make it operate at all, or else, if the oil does not contain such a residuum liable to become thick and heavy, it will leave the bearing dry.

3. All the mineral oils—and also sperm, lard, and neat's-foot oils—appear to reach a nearly uniform coefficient of friction at very greatly different degrees of heat in the bearings. Several kinds of the best mineral oils and sperm and lard oils show a uniform coefficient of friction at the following degrees of heat:

TEMPERATURE AT WHICH THE COEFFICIENT OF FRICTION IS THE SAME.

	Deg. F.
32° machinery (an exceedingly fluid oil)	76
Light spindle	105
Heavy spindle	125
Various samples of sperms	96 to 114
Valvoline spindle	127
White valvoline spindle	122
White loom	111
German spindle	112
A spindle	107
Neat's-foot	170
Lard oil	180

4. Lubrication seems to be effective in adverse ratio to viscosity, *i. e.*, the most fluid oil that will stay in its place is the best to use. Lard oil heated to 130° lubricates as well as sperm at 70° or the best mineral oil at 50°. But of course it is a great waste of machinery to work oil of any kind up to an excessive heat, and there must be the least wear in the use of oil that shows the least coefficient of friction at the lowest degree of heat.

5. The quantity of oil used is a matter of much less importance than the quality. The mill that saves gallons of oil at the cost of tons of coal or dollars of repairs plays a losing game. Mr. Waite's experiments on very heavy bearings at Manchester go far to prove that a considerable quantity of thin fine oil keeps the bearings much cooler and requires less power than a smaller quantity of thick viscous oil. Here let it be observed that a superstition that prevails in favor of using castor oil to cool a hot bearing is without any warrant. No vegetable oil is fit to use as a lubricant; and castor oil is the worst of all, because the most viscous. If used, it will surely set the mill on fire, as it did in the only case of which we have a record.

6. The rule of best lubrication is to use an oil that has the greatest adhesiveness to metal surfaces and the least adherence as to its own particles. Fine mineral oils stand first in this respect, sperm second, neat's-foot third, lard fourth.

7. Cast-iron holds oil better than any other metal or any alloy, and is the best metal to use for light bearings, perhaps for heavy.

8. It has been proved by Mr. Waite's experiments that a highly-polished bearing is more liable to friction than a surface finely lined by filing. The lines left by the file serve as reservoirs for the oil, while the high polish leaves no room for the particles between the metal surfaces.

So far as laboratory experiments may serve as a guide in practice, it therefore appears that fine mineral oils may be made to serve all the purposes of a cotton-mill, and such is the practice in some of the mills that show the very best results in point of economy; next, that the best animal oil to mix with a fine mineral oil, in order to give it more body, is sperm oil; this again accords with the practice of many of the mills in which the greatest economy is attained. Lard and neat's-foot oil are used to give body to mineral oil in some of the best mills; but the results of our work seem *not* to warrant this practice, unless there is some peculiarity in the machinery that makes it more difficult to keep a less viscous or tenacious oil on the bearings. All the mixed oils sold under fancy names we believe must, of necessity, consist of certain proportions of the oils heretofore named, as none of the vegetable or fish oils are fit to be used, and there are no other animal oils that can be had in any quantity. It appears that all varieties of mineral oils are or have been used in print-cloth mills, and are all removed in the process of bleaching, as practiced in print-works. All mineral oils stain more or less, and give more or less difficulty to the bleacher when dropped upon thick cloth or cloth of a close texture. On this point we have been able to establish no positive rule; but as very many kinds are and have been used in mills working on such cloths and are removed we are inclined to the belief that this question is not of as great importance as it has been assumed to be.

These exact results have been obtained under conditions of great velocity and low pressure. Professor Thurston's remarks, quoted on a previous page, apply to the conditions of friction under great pressures and slow motion. We have not, however, yet subjected the lubrication of heavy bearings to so exhaustive a research. Dr. C. B. Dudley, chemist to the Pennsylvania Railroad Company, has been devoting much time recently to the investigation of lubricants for railroads. His results have not been made public. This road and other leading railroads of the country are among the heaviest purchasers of natural lubricating oils that will not thicken at a low temperature. Oils of this quality, as well as reduced oils, are very largely used on railroads, as also some of the petroleum mixtures, such as the "pine-tar compound", the "galena oils", and the "plumbago oils".

A report of a committee of the Railway Master Mechanics' Association of the United States, appointed to examine into and report on the subject of lubricants, recommended a good quality of natural earth oils as the best to use for lubricating machinery and journal boxes. It is less expensive and of a better quality than other oils. When treated so as to reach 28° of gravity, it was found to work with perfect success. It had been reported favorably on from Canada in the north to Kentucky in the south. A test of various oils had been made with the oil-tester on the Lake Shore road; sperm, lard, and tallow were used, and none of them were found to possess qualities which render their use advisable. In their experiments the committee used a machine the size of a regular axle-box, and 50 drops were poured in at a temperature of 60°, and the wheel was allowed to revolve at a rate of speed equaling 35 miles per hour until a temperature of 200° was reached. The length of time, number of revolutions, and amount of friction were all noted. Attention was called to the result obtained from tests with paraffine oil which costs from 25 to 30 cents per gallon, and which has been used on railroads in preference to lard oil. Paraffine oil costing 25 cents, with which six experiments had been made, showed that twenty-four minutes were required to reach the maximum temperature, during which time it gave 11,685 revolutions; castor oil, costing $1 25, which required twenty-eight minutes to reach the temperature allowed, gave 12,946 revolutions; manufactured oils—A, B, and C—costing 35 cents, 90 cents and 25 cents, respectively, required nineteen and one-half minutes, giving from 9,285 to 9,653 revolutions; sperm and tallow required only seventeen minutes to reach 200° temperature, with less than 8,000 revolutions. (*a*)

Paraffine oil that does not boil under 370° C. has been considered the best material for lubricating cylinders at high temperatures. Mineral oil, purified by being shaken with chlorinated soda, from which it is decanted and then shaken repeatedly with milk of lime, and again decanted and then distilled with one-third its volume of solution of caustic soda, is used for the lubrication of watches. (*b*)

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a Iron Monger, Supplement, Dec. 13, 1879.

b Poly. Cbl. 1859, 575.

Chapter II.—THE USES OF PETROLEUM AND ITS PRODUCTS FOR ILLUMINATION.

Section 1.—INTRODUCTION.

Crude petroleum has been used in Japan and Burmah for purposes of illumination from an immemorial period. In Burmah the Rangoon tar or oil was burned in earthen lamps. In Persia pencils of dried dung were saturated with the oil and burned, the pencil serving as a wick. In Parma and Modena and other towns in the upper valley of the Po the native petroleum, which is quite fluid and of a light color, has been burned for years both in street lamps and in dwellings. In the valley of Oil creek, and in the salt region of the lower Allegheny and Kiskiminetas, the petroleum obtained from springs and from the salt-wells was used in a contrivance resembling a tea-kettle, often with two spouts (see Fig. 19), for lighting saw-mills and derricks. For these purposes the amber oils of the lower Allegheny were considered superior to the dark oil of Oil creek.

Since the manufacture of petroleum by distillation was commenced there have been several separate products used for illuminating purposes. Most of the illuminating oils have been called "kerosene", a name which was originally adopted as a trade-mark by some firm engaged in the manufacture of coal-oils, but which soon afterward became a common designation applied to a certain class of oils used in common lamps. This word, however, has not been uniformly applied to a substance of uniform kind and quality, but has been used to designate a class of substances prepared in a similar manner from a common crude material, but which in certain respects present a very wide variation. The varieties known to the trade are "Water White", "Standard," and "Prime", the distinctions on which the classification is based relating chiefly to color. There are, however, wide differences between the oils as manufactured by different methods that exist independently of color. The oils may contain too large a proportion of the volatile products of the petroleum; they may contain too large a proportion of the heavy products; they may contain too large a proportion of cracked material; and yet in either case they may, by judicious manipulation, be made to appear of good color while otherwise of inferior quality—a fact which in this country has been almost overlooked, but which has lately attracted some attention in Germany, and will doubtless be more carefully regarded in future. "Color" and "test" have hitherto determined the quality of competitive illuminating oils, but a more careful regard for the quality of such oils would lead to the determination of the relative proportion of light and heavy constituents and the condition of the oil with reference to the presence and amount of sulphur compounds. The quality of oils with reference to these two particulars is not determined by either the color or the test, but a disregard of them seriously affects the quality of the oil as an illuminator. (*a*) A few years since legislation was obtained in Minnesota which excluded low-test oils from the markets of that state. The following season those markets were stocked with oils, which, to use the English phrase, were mixtures of "tops and bottoms". They were up to the legal test, and were satisfactory in color, but they would become solid at —20° F., and were so heavily charged with sulphur compounds that they blackened at a temperature of 200° F. They were of very inferior quality, and were very successfully used in securing the repeal of the legislation of the preceding winter.

In addition to the ordinary illuminating oils which vary in the manner stated above, the naphthas of different grades have been used in lamps of different kinds. The best lamp in all respects for burning naphtha is that known as the sponge lamp. This lamp is made in a variety of forms, and is filled with sponge, which, on being saturated with the fluid, yields it to the wick and prevents either the spilling of the contents of the lamp or an explosion when the fluid is consumed and air becomes mingled with the vapor. Naphtha is also used in lamps of peculiar construction which have been found especially useful for lighting streets. These lamps are so constructed that the heat of the flame vaporizes the naphtha as it passes through a tube from a reservoir to the burner, where the vapor is burned as if it were a gas jet. This form of lantern is very extensively used, especially in the environs of cities.

Another oil is "mineral sperm", which is distilled from the crude paraffine oils in the preparation of lubricating oils. This oil has a very high boiling point, and flashes at a temperature above 275° F. It is chiefly used in lighting mills, steamboats, and railroad cars, where more easily inflammable oils would be objectionable.

Section 2.—SAFE OILS.

While the color of oils is to some extent an indication of their quality, the flash or fire test is the principal guarantee upon which the general public relies for both quality and safety; yet, as has been already stated, the burning qualities are not represented by them. The discussion of the subject of *safe* oils was commenced at a very early date. Among the earliest papers connected with this subject is one published in the *Report of the*

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a See *Vohl's Research*, page 181.

Smithsonian Institution for 1862 by the Hon. Zachariah Allen, of Providence, Rhode Island. In this paper Mr. Allen states that the experiments therein described were undertaken at the instance of the Rhode Island Mutual Fire Insurance Company. The experiments were too simple to be deserving of particular notice here, but the discussion of the subject not only exhibits the acuteness with which the author was accustomed to treat technological questions, but also shows how few facts have been added to the sum of human knowledge concerning the products distilled from petroleum during the twenty years that have elapsed since his paper was written. He says:

To ascertain the comparative qualities of the kerosene oil made in different parts of this country samples were procured and tested by the simple process of pouring some of each kind of oil into a cup by itself, and by placing them all afloat together in a basin of water heated by a spirit lamp, and with a thermometer immersed in the water to indicate the temperature while gradually rising from 60° to 212°. During the progress of the increase of temperature blazing matches were passed over the surface of the oil in each cup successively at short intervals of time, until the increased heat caused sufficient gaseous vapors to arise from each to take fire, which they all finally did, at degrees of temperature varying from 80° to 162°, exhibiting faint flames quivering over the surface of the oil, precisely like those hovering over the surface of spirits of wine or alcohol when similarly kindled. The flames are quite as readily extinguished by a blast of the breath, and not the least symptom of any explosive character became manifest when each one took fire. Until the evaporative point of each sample of oil was produced by the increase of heat applied, and until lambent flames were kindled, burning matches were extinguished when plunged into the coal-oil as effectually as if they had been similarly plunged into water. The average heat at which all the samples emitted sufficient vapor to admit of being kindled was about 125° of Fahrenheit's scale. After ascertaining the temperature requisite to kindle the several samples of coal-oil, it next becomes an interesting subject of investigation to ascertain the heat to which coal-oil is ordinarily elevated while burning in lamps. The results of actual experiments showed that in glass lamps the temperature is increased about 6° and in metallic lamps but 10° or 12° above that of the apartment, which, being 67°, produced a heat in the oil of about 71° to 79°, leaving a considerable range of temperature below the average of 125° above stated. Finding by actual observation that only gaseous vapors arising from the heated oil exhibit the phenomenon of flame whilst ascending and combining chemically with the oxygen of the air, it became manifest that no explosive action could be anticipated to take place from any kind of oil or inflammable spirits unless these gaseous vapors were first evolved by a previous increase of temperature, and then brought into contact with the atmospheric air before applying a match thereto. There being no room left for either the gaseous vapor of the oil or for atmospheric air to combine therewith in the chamber of any lamp entirely filled with oil. every attempt to produce explosive action with a full lamp, at all temperatures up to the boiling point of water, utterly failed when lighted matches were applied to the open orifice of the lamp. The only result produced by increasing the heat of the coal-oil was an increase in the evaporation of the gas, and a higher jet of flame steadily rising, as from the jet of a gas burner. So long as lamps are kept FULL of oil, or even of explosive camphene or "burning fluid", there can be no explosive action whatever. *For this special reason it may be adopted as a safe rule to cause all* lamps containing highly inflammable liquids to be kept as full as practicable by being daily replenished.

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As the dangerous inflammability of coal-oil appeared to be ascribable to the naphtha not separated therefrom, the following experiments were made to ascertain the extent of the inflammable properties of pure naphtha. Finding that the liquid naphtha evolved sufficient vapors at the ordinary temperature of the atmosphere to become instantaneously kindled into flashing flames, the cup containing it was immersed in a freezing mixture of snow and salt to reduce the temperature to the zero of Fahrenheit's scale. At this low temperature the naphtha appeared to blaze with equal violence. Then a quantity of snow was mixed with the liquid naphtha and thoroughly stirred, for still further reducing the temperature. Even at this extreme degree of cold the naphtha continued to flame so furiously that it was necessarily thrown from the cup upon the ice covering the ground where the experiment was made, in the open air, whilst the thermometer indicated an atmospheric temperature of 19° below the freezing point. The naphtha still continuing to burn upon the surface of the ice, a covering of snow was thrown over it to extinguish the flame. Through this covering of white snow the bright flames still continued to shoot up, presenting to view the extraordinary spectacle of burning snow. On repeating similar experiments on the comparative combustibility of spirits of wine or alcohol, camphene, and burning fluid, they did not emit sufficient gaseous vapors at the freezing point, or 32°, to become kindled into flame when burning matches were plunged therein, but with a little increase of temperature they all became kindled. The preceding experiments seem to exhibit impressively the extraordinary inflammability of naphtha, arising from the facility with which it emits gaseous vapors; the utmost caution is requisite to prevent not only unexpected explosions, but also the almost unextinguishable violence of its conflagration, for practically the application of water does not subdue the conflagration of naphtha in quantity, and only the exclusion of atmospheric air appears to quench the fury of its flames. * * * Petroleum contains a considerable percentage of naphtha, and consequently partakes in a degree of its dangerous properties. * * * In making experiments with the tin vessel of the capacity of a common lamp a single drop of naphtha was found to yield sufficient vapor to produce as much explosive action as could be produced by the most inflammable coal-oil for sale in the market when similarly experimented with; and after every experiment failed to exhibit the slightest explosive tendency of the best kerosene oil, a single drop mingled therewith rarely failed to yield sufficient vapor to manifest its presence by a slight explosive puff when kindled by a lighted match. (*a*)

These experiments, made in 1862, satisfied Mr. Allen, as a representative of very large manufacturing and insurance interests, that "coal-oil" (*i. e.*, mineral illuminating oil), when properly manufactured by responsible parties, was a safe material for use; and they also established these fundamental facts, which have been made the basis of all the action that has since been taken with reference to this question, viz: That the volatile constituents of petroleum are extremely inflammable liquids; that they mingle with the air with great readiness and form mixtures that explode with great violence; that illuminating oil prepared from coal or petroleum, from which these oils, volatile at a low temperature, are carefully excluded, is a safe illuminating material for ordinary use, while the presence of a very small percentage of the naphtha, added to an oil of unquestioned excellence, produces a dangerous mixture, from the use of which explosions and conflagrations are liable to ensue.

The continued agitation of this subject led to legislation by states, cities, and towns, and also to the manufacture of such oils as would satisfy the requirements of the various laws enacted. The result has been the establishment of different tests, that is, different degrees of temperature at which the oils might produce an explosive

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a *Rep. Smithsonian Inst.*, 1862, p. 330. The name is here erroneously given T. Allen.

vapor or burst into flame. The tests were therefore classified as flash tests and fire tests, and both classes include a range of temperatures between 75° and 175° F. Both the classes of tests have had their advocates; and to meet the requirements of law with most profit on the one hand, and to protect the public in the use of these oils on the other, a large number of apparatus and a variety of methods for their use have been devised.

The conclusions reached by Mr. Allen, that an oil properly manufactured is safe, while one containing naphtha is dangerous, suggests the further conclusion that there must be two standards: one of relative and the other of absolute safety. The object of establishing any test is *simply to determine at what temperature a given sample of illuminating oil, in quantity sufficient to fill a lamp of ordinary size, gives off enough vapor, which, when mingled with air, can form an explosive mixture.* It therefore becomes a matter of merely secondary importance at what temperature such an oil will take fire, as all experience has shown that an explosion has been followed by fire in so many instances that the question of the temperature at which an explosive oil will take fire becomes eliminated as worthless; because the temperature at which an oil will take fire is acknowledged by all parties at all acquainted with the facts to be no indication whatever of the temperature at which such an oil will flash. It is immediately asked, if such is the case, why is a fire test ever used? It is sufficient to answer, that it is much less difficult to manufacture oils of a uniform *fire* test than of a uniform *flash* test; hence the efforts of some manufacturers have always been used to secure legislation requiring a *fire* test rather than a *flash* test, and legislators have listened to the presentation of practical difficulties rather than to the objections presented by physicists and philanthropists who have urged the claims of the flash test.

As illustrating the inadequacy of the fire test to protect life and property by detecting dangerous oils, of seven hundred and thirty-six samples of oil examined for the New York city health department more than half did not take fire below 110°, while only twenty-three failed to evolve inflammable vapors below 100°.

Returning to the question of absolute safety, we immediately seek to follow Mr. Allen in his inquiries respecting the temperature attained by the oil while burning in lamps under ordinary conditions. The most elaborate research on record is that undertaken by Dr. C. F. Chandler and published in 1871 in his celebrated report on petroleum as an illuminator. (*a*) The following extract from this report gives the conclusion reached:

THE TEMPERATURE OF OIL IN BURNING LAMPS.

FIRST SERIES.—TEMPERATURE OF THE ROOM, 73° TO 74° F.

No.	Kind of lamp.	Capacity of lamp.	TEMPERATURE OF THE OIL.				
			After one hour.	After two hours.	After four hours.	After seven hours.	Average for seven hours.
		Ounces.	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
1	Brass hand-lamp	8	85	82	85	86	84.5
2	Brass hand-lamp	24	79	83	84	82	82.0
3	Glass stand-lamp	8	77	78	79	80	78.5
4	Glass stand-lamp	11	77	81	84	82	81.0
5	Glass stand-lamp	20	78	79	79	80	79.0
6	Glass stand-lamp	7	82	80	85	84	82.75
7	Glass stand-lamp	10	84	36	84	82	84.0
8	Glass hand lamp	9	79	78	85	85	81.75
9	Glass hand-lamp	6	81	82	86	86	83.75
10	Glass hand-lamp	7	80	78	....	....	79.0
11	Brass student-lamp	13	82	80	83	84	82.25
12	Glass stand-lamp	10	81	81	79	78	79.75
13	Brass stand-lamp	11	92	89	88	86	88.75
14	Tin lantern	7	89	86	88	87	87.5
15	Glass bracket-lamp	19	82	82	84	83	82.75
16	Glass stand-lamp	29	82	80	80	84	81.5
17	Brass student-lamp	7	80	....	88	....	84.0
18	Brass stand-lamp	14	84	85	87	87	85.75
19	Brass stand-lamp	12	100	100	92	91	95.75
20	Metal stand-lamp	9	82	82	88	87	84.75
21	Brass stand-lamp	12	91	92	88	85	89.0
22	Bronze stand-lamp	16	83	76	79	85	80.75
23	Glass hand-lamp	....	79	80	82	82	80.75

a Am. C., ii, 409, 446; iii, 20, 41; Mon. Sci., 1872, 676, Dingler, ccv, 587; D. Ind. Z., 1872, 376; W. B., 1872, 873.

With the air of the room at from 73° to 74° F. the temperature of the oil in the burning lamps ranged from 76° to 100° F., the highest temperature of 100° having been reached in a metal lamp at the end of one hour. That this was an exceptionally high temperature is shown by the fact that the highest temperature reached in any other lamp was 92° F. The following is a synopsis of the observations:

	In 23 lamps.	In 11 metal lamps.	In 12 glass lamps.
	Deg. F.	*Deg. F.*	*Deg. F.*
Highest temperature reached	100	100	86
Lowest temperature reached	76	76	76
Average temperature	83	86	81

SECOND SERIES.—TEMPERATURE OF THE ROOM, 82° TO 84° F.

No.	Kind of lamp.	Capacity of lamp.	Temperature of the oil. After one hour.	After two hours.	After three hours.	After four hours.	Average for four hours.
		Ounces.	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*
	Air of room		82	83	84	83	83
1	Brass hand-lamp	8	92	95	96	95	94.50
2	Brass hand-lamp	24	88	94	94	93	92.25
3	Glass stand-lamp	8	84	88	86	84	85.50
4	Glass stand-lamp	11	84	86	86	84	85.00
5	Glass stand-lamp	20	85	86	87	86	86.00
6	Glass stand-lamp	7	86	87	88	88	87.25
7	Glass stand-lamp	10	88	87	89	88	88.00
8	Glass hand-lamp	9	87	90	90	90	89.25
9	Glass hand-lamp	6	87	91	89	87	88.50
10	Glass hand-lamp	7	84	86	86	84	85.00
11	Brass student-lamp	13	86	88	88	88	87.50
12	Glass stand-lamp	10	85	86	86	85	85.50
13	Brass stand-lamp	11	104	103	101	101	102.25
14	Tin lantern	7	95	96	94	96	95.25
15	Glass bracket-lamp	19	84	85	84	84	84.25
16	Brass stand-lamp	29	84	85	84	84	84.25
17	Brass student-lamp	7	87	88	86	84	86.25
18	Brass student-lamp	14	91	93	92	91	91.75
19	Brass stand-lamp	12	101	100	98	96	98.75
20	Metal stand-lamp	9	89	92	94	93	92.00
21	Brass stand-lamp	12	88	98	94	96	94.00
22	Bronze stand-lamp	16	82	88	88	89	86.75
23	Glass hand-lamp	6	84	86	85	84	84.75
24	Brass student-lamp	10	120	120	120	118	119.50
25	Brass student-lamp	12½	112	115	115	116	115.00

With the air of the room at from 82° to 84° F, the temperature of the oil in the burning lamps ranged from 82° to 120° F. The temperature 120° was exceptional, being confined to one lamp.

SYNOPSIS OF THE OBSERVATIONS.

	In 26 lamps.	In 13 metal lamps.	In 12 glass lamps.
	Deg. F.	*Deg. F.*	*Deg. F.*
Highest temperature reached	120	120	91
Lowest temperature reached	82	82	84
Average temperature	91½	96½	86

THIRD SERIES.—TEMPERATURE OF ROOM, 90° TO 92° F.

No.	Kind of lamp.	Capacity of lamp.	TEMPERATURE OF THE OIL. After one hour.	After two hours.	After three hours.	After four hours.	Average for four hours.
		Ounces.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
	Air of room	....	92	90	92	90	91
1	Brass hand-lamp	8	90	98	100	98	96.50
2	Brass hand-lamp	24	89	98	102	100	97.25
3	Glass stand-lamp	8	88	90	93	94	91.25
4	Glass stand-lamp	11	88	92	94	94	92.00
5	Glass stand-lamp	20	85	92	94	94	91.25
6	Glass stand-lamp	7	90	94	96	93	93.25
7	Glass stand-lamp	10	90	96	96	96	94.50
8	Glass hand-lamp	9	88	95	98	98	94.75
9	Glass hand-lamp	6	89	95	96	97	94.25
10	Glass hand-lamp	7	88	92	93	94	91.75
11	Brass student-lamp	13	89	100	102	102	98.25
12	Glass stand-lamp	10	88	92	93	93	91.50
13	Brass stand-lamp	11	106	114	116	110	111.50
14	Tin lantern	7	99	106	107	105	104.25
15	Glass bracket-lamp	19	85	92	91	91	89.75
16	Glass stand-lamp	29	86	91	92	92	90.25
17	Brass student-lamp	7	92	99	100	100	97.75
18	Brass student-lamp	14	94	100	100	100	98.50
19	Brass stand-lamp	12	108	112	112	107	109.75
20	Metal stand-lamp	9	91	96	100	99	96.50
21	Brass stand-lamp	12	104	110	108	106	107.00
22	Bronze stand-lamp	16	84	90	95	98	91.75
23	Glass hand-lamp	6	90	92	94	94	92.50
24	Brass student lamp	10	124	129	129	128	127.50
25	Brass student-lamp	12½	120	126	127	127	125.00

With the air of the room at from 90° to 92° F. the temperature of the oil in the burning lamps ranged from 84° to 129° F., the highest temperature being exceptional.

SYNOPSIS OF THE OBSERVATIONS.

	In 25 lamps.	In 13 metal lamps.	In 12 glass lamps.
	Deg. F.	Deg. F.	Deg. F.
Highest temperature observed	129	129	98
Lowest temperature observed	84	84	85
Average temperature observed	98¾	104½	92⅓

By these results it appears that the temperature of the oil in lamps often rises much above 100° F., thus reaching a temperature at which oil, *which does not emit a combustible vapor below* 100° *F.*, would be dangerous. It is apparent that 100° F. is too low a standard for safety; 120° F. would not be too high a standard, and its adoption would not add three cents per gallon to the cost of the oil.

An analysis of these tables shows that when the temperature of the room was 73° to 74° (a comfortable temperature) only one lamp in twenty-three reached a temperature of 100°, and no glass lamp reached a temperature of 90°, and that the average temperature of the twenty-three lamps was only 83° F. The average temperature of the eleven metal lamps was 5° higher than that of the twelve glass lamps. When the temperature of the room was 82° to 84° (quite warm for comfort) only one lamp in twenty-five reached a temperature of 120°, and only two glass lamps reached a temperature of 90°, the highest reaching 91°. The average temperature of the twenty-five lamps was 91½° F. The average temperature of the thirteen metal lamps was 10½° higher than that of the twelve glass lamps. When the temperature of the room was 90° to 92° F. (an uncomfortably high temperature) only two lamps out of twenty-five reached a temperature of 120°, and no glass lamp reached a temperature of 100°, and the average temperature of the twenty-five lamps was only 98¾° F. The average temperature of the thirteen metal lamps was 12⅙° higher than that of the twelve glass lamps. Moreover, in the seventy-three lamps tested, but twelve reached a temperature above 100°, and but six above 110°. A series of experiments were described by H. B. Cornwall, (*a*) in 1876, which were made with the design of showing how much naphtha must be removed from a low-test oil to bring it up to safety. His results are tabulated on page 219.

a Am. Chem., vi, 458.

No.	Sp. gr.	Time.	Flashing point.	Time.	Burning point.
	Deg. B.	*Minutes.*	*Deg. F.*	*Minutes.*	*Deg. F.*
1	49.7	21	86	7	107
2	....	25	96	8	112
3	48.7	....	110	....	124
4	47.1	15	80	7	100
5	45.3	23	121	5	138
6	....	12	98	5	113
7	50.4	23	118	6	135
8	45.8	12	104	5	125
9	....	23	104	5	120
10	....	23	81	....	....

No. 1 was an oil flashing at 86° and burning at 107°. He distilled off 4 per cent., and the residue (No. 2) flashed at 96° and burned at 112°. He then distilled off of another portion of the same oil 10.6 per cent., and the residue (No. 3) flashed at 110° and burned at 124°. On mixing the distillate and the residue in proper proportions the mixture flashed at 89° and burned at 107°, almost at the identical temperatures with the original oil No. 1. An oil worse than No. 1 (No. 4) was then distilled until 12.7 per cent. of distillate was secured with 2.7 per cent. of loss. The residue (No. 5), which was very dark, flashed at 121° and burned at 138°. Five per cent. of distillate was removed from another portion of the same sample, and the residue, after treatment with sulphuric acid and soda, gave No. 6, which flashed at 98° and burned at 113°. The following table embraces some experiments made with mixtures of oils and naphtha, and includes some results obtained by Dr. C. B. White, of New Orleans, Louisiana:

Oils.	Flashing point.	Difference.	Burning point.	Difference.
No. 7. Table I:	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
Alone	118	....	135	....
+ 1 per cent. naphtha of 65° B	112	6.0	129	6.0
+ 3 per cent. naphtha of 65° B	103	5.0	123	4.0
+ 5 per cent. naphtha of 65° B	96	4.4	116	3.8
+10 per cent. naphtha of 65° B	83	3.5	102	3.3
+ 1 per cent. naphtha of 71.7° B	107	11.0	133	2.0
+ 5 per cent. naphtha of 71.7° B	Below 70	....	105	6.0
No. 8. Table I:				
Alone	104	....	125	....
+ 2 per cent. naphtha of 65° B	96	4.0	120	2.5
+10 per cent. naphtha of 65° B	76	2.8	107	1.08
Dr. White's oil:				
Alone	113	....	....	....
+ 1 per cent. naphtha of 65° B	103	10.0	....	....
+ 2 per cent. naphtha of 65° B	92	10.5	....	....
+ 5 per cent. naphtha of 65° B	83	6.9	....	....
+ 10 per cent. naphtha of 65° B	59	5.4	....	....
+ 20 per cent. naphtha of 65° B	....	....	50	....

The naphtha of specific gravity 65° B. is termed *benzine*, the commercial naphtha having a specific gravity of 70° to 76°. The columns marked "Difference" show the average difference for each per cent. of naphtha added. The naphtha used by Dr. White was lighter than 65° B. A series of experiments was undertaken to show the difference in two consecutive tests for flashing point made upon the same sample of oil, after allowing the oil to cool between the tests. The difference was found to be from 3° to 4°.

Probably the greatest danger from kerosene lamps arises from the risk of overturning and breaking the lamp, although undoubtedly explosions sometimes break lamps. A series of experiments were undertaken with a view to ascertaining the action of oils of different quality under conditions similar to those attending a broken lamp.

Thin glass flasks were provided with corks, through which passed tubes holding wicks. The oil in each flask was then heated in a water bath to 95° F., and the wick lighted, after which the flask was dropped on a brick floor near a steam boiler, the bricks having a temperature of about 93° F. The results are given in the following table. No. 8 was a mixture of No. 1 with 5 per cent. of naphtha of 65° B., and No. 9 of No. 1 with 5 per cent. of naphtha of 71.7° B.; the others were bought from dealers.

No.	Flashing point.	Burning point.	Remarks.
	Deg. F.	*Deg. F.*	
1	118	135	The wick continued to burn quietly without igniting the spilled oil.
2	104	120	Like No. 1.
3	100	112	Do.
4	98	116	Part of the oil was slowly ignited.
5	96	111	All of the oil at once took fire.
6	80	100	Like No. 5.
7	80	98	Do.
8	96	116	Do.
9	Below 70	105	Ignited with a flash.

From the above experiments the following conclusions may be drawn, as applying at least to these oils:

1. The naphthas distilled were comparatively heavy, 59° to 64° B., technically known as benzines.

2. The removal of about 10 per cent. of these naphthas from an average unsafe oil raised the flashing point 2.27° and the burning point 1.60° F. for each per cent. removed; the addition of the same proportion of naphtha of equal specific gravity lowered the flashing point in very nearly the same ratio.

3. The second table shows that a paying amount of a light naphtha above 70° B. could not be added to even a very high grade oil without making it conspicuously bad, while as much as 10 per cent. of a heavier naphtha (benzine) of 65° B. could be added to an oil of a little above 100° F. flashing test, and make it no worse than much of the oil now in the market.

4. When a small amount of naphtha of above 70° B. is added to a good oil the flashing point is lowered much more rapidly than the burning point; if the oil is of very high grade and the naphtha moderately heavy, 65° B., the burning point of the oil is lowered almost as rapidly as the flashing point, while the addition of a naphtha of 65° B. to a moderately good oil, flashing at 104° F., lowers the flashing point 35 to 40 per cent. more rapidly than the burning point.

5. The burning point is not a reliable test of the safety of an oil, since oils, when spilled, will ignite instantly on the approach of a flame when heated a degree or two above their flashing point, even although the burning point is 10° or 20° F. higher. (*a*)

6. The first two tables show that an oil flashing at 86° and burning at 107° F. can be made to flash at 100° by removing 6 or 7 per cent. by distillation. This corresponds nearly with the estimate * * * that average petroleum yielding 75 per cent. of 110° F. "fire test" (burning test) oil would probably yield 69 per cent. of 100° "flash oil"; in other words, 8 per cent. of the 110° "fire test" oil would have to be removed to make a 100° "flash" oil. The average flashing point of eight oils given in Dr. Chandler's report as burning at 110° F. was 89°. (*b*)

These conclusions were stated with equal emphasis by Dr. Chandler in his report, from which I have already quoted. He says:

There are two distinct tests for oil: (1) *the flashing test,* (2) *the burning test,* which are often confounded; and when the law or ordinance specifies the *fire test* there is a doubt as to which of the two tests is intended. *The flashing test* determines *the flashing point* of the oil, or the lowest temperature at which it gives off an inflammable vapor. This is by far the most important test, as it is the inflammable vapor, evolved at atmospheric temperatures, that causes most of the accidents. Moreover, an oil having a high flashing test is sure to have a high burning test, while the reverse is not true. *The burning test* fixes the burning point of the oil, or the lowest temperature at which it takes fire. The burning point of an oil is from 10° to 50° F. higher than the flashing point. The two points are quite independent of each other; the flashing point depends upon the amount of the most volatile constituents present, naphtha, etc., while the burning point depends upon the general character of the whole oil. Two per cent. of naphtha will lower the flashing point of an oil 10° without materially affecting the burning test. The burning test does not determine the real safety of the oil; that is, the absence of naphtha. The standard which has been generally adopted as a safe one fixes the flashing point at 100° F. or higher, and the burning point at 110° or higher. In the English act and some of * * * the laws of the states of the American Union the burning test has been very judiciously omitted, as two distinct tests are often confusing, and, moreover, the burning test or point is not an index of the safety of the oil. More than half of all the samples of oil which have been tested for the health department (of New York city) did not take fire below 110° F.; consequently they were safe according to the burning test; but only twenty-eight of seven hundred and thirty-six samples w really safe, all the rest evolving inflammable vapors below 100° F. *The flashing test* should therefore be the only test mentioned in laws framed to prevent the sale of dangerous oils. (*c*)

In 1873 a committee of the Franklin Institute, of Philadelphia, reported "On the causes of conflagrations and the methods of their prevention". This committee reported that in 1872 the number of fires occurring in Philadelphia was 41¼ per cent. greater than in the previous year. Of these fires, 59 (the largest number originating from any one source) were caused by explosions of coal-oil and fluid lamps. The report further states:

The number of deaths in the United States from the explosions of coal-oil and fluid lamps in 1871 was, by the account kept by an insurance paper (the *Chronicle*), 3,500. If the death rate for 1872 kept pace with the increase of conflagrations, which was about 50 per cent., it would give for the past year (1872) 5,250 deaths, and the maiming of probably 20,000 persons within the jurisdiction of the United States.

Statistics of this character could be extended indefinitely.

Regarding the nature of petroleum products, this committee report:

We find by actual experiments that all the light forms of petroleum (products) constantly generate vapor or gas even at the low temperature of 12° above zero. * * * Any oil or burning fluid that evaporates rapidly or generates gas below 100° is exceedingly unsafe. * * * It is not the oil or fluid that explodes, but the vapor mixed with air. * * * When the mixture goes on so that there is one part of gas and four parts of atmospheric air inside the lamp, or when these proportions exist in a room or any other apartment, they form a fearfully explosive mixture. * * * Volatile oils and combination burning fluids generate vapor inside the lamp, hence the less the oil the greater the vacant space filled with vapor and atmospheric air and the greater the danger, and hence it is apparent that to fill a lamp nearly empty while burning is almost certain to result in a terrific explosion.

This report was accompanied by another, in which the subject was discussed by the then secretary of the institute, William H. Wahl, esq. In this report Dr. Wahl reviews the subject in great detail, and reaches the same conclusions as Dr. Chandler, above quoted. (*d*)

I have already referred to the elaborate research of Dr. J. Biel, of Saint Petersburg, upon the comparative value of American and Russian petroleum, published in Dingler in 1879. (*e*) After reviewing the comparative production of America and Russia, in which he shows that the average yearly yield of a Caucasian well is three times as great as that of an American well, he refers to the "special general meeting of the Petroleum Association" held in London on the 14th of January, 1879, at which Mr. F. W. Lockwood, of New York, was present, and the representations there made, that the illuminating oils produced from the petroleum of the Bradford district were not of the same

a See in this connection Chandler's report, *Am. Chem.*, iii, 42.
b *Am. Chem.*, vi, 458.
c *Am. Chem.*, iii, 42; *Mon. Sci.*, 1872; Dingler, ccv; W. B., 1872.
d *Jour. Frank. Inst.*, xcv, 267.
e Dingler, ccxxxii, 354.

quality as those exported from the United States in previous years and manufactured from the petroleum of the Parker (Butler and Clarion) district. He then goes on to say that the American oils offered for sale were very inflammable and were deficient in illuminating power; that they burned well for a few hours, and that during the succeeding hours, in order to maintain the illumination, it was necessary to raise the wick at short intervals, the result of which was finally the accumulation of carbon upon the wick. In order to determine the cause of this trouble Dr. Biel selected three American kerosenes, Pratt's astral oil, and several specimens of Russian kerosene, and subjected them to fractional distillation in a glass retort with a thermometer immersed in the oil. That portion distilling below 150° C. (302° F.) he called *essence* (essenzen); that portion coming over between 150° and 270° (518° F.) he called *burning oil* (brennöle); and that above 270° he called *heavy oil* (schwere Oele). The three American kerosenes were *Carbon oil* of the Standard Oil company, of Cleveland, Ohio; *Standard oil* of the Imperial Refining Company, of Oil City, Pennsylvania; and *Standard White*, of unknown manufacture. The three oils gave practically the same results, as follows:

1. *Standard oil*, specific gravity 0.795, flash point 26° C. (78° F.), burning point 30° C. (86° F.); concentrated sulphuric acid in equal parts with the oil is colored blackish brown upon being shaken with it. Tension of vapor according to Salleron, 160^{mm} at 35° C. The distilled products were:

Temperature.	Per cent.	Specific gravity.	Burning point.	
Deg. F.		*Deg. B.*	*Deg. C.*	*Deg. F*
(*a*) 125 to 150	14.4	0.741 = 59	16	(162)
(*b*) 150 to 170	9.8	0.760 = 54	29	(85)
(*c*) 170 to 190	8.3	0.770 = 52	43	(110)
(*d*) 190 to 210	6.0	0.778 = 50	59	(140)
(*e*) 210 to 230	5.6	0.786 = 48	75	(167)
(*f*) 230 to 250	8.6	0.796 = 46	100	(212)
(*g*) 250 to 270	7.6	0.808 = 43	112	(233)
(*h*) 270 to 290	5.8	0.818 = 41	....	....
(*i*) Residue ...	33.9	0.840 = 37½	....	....

I have given the equivalents of the specific gravity and temperatures in degrees of Baumé and Fahrenheit.

The distillation was accompanied with a copious evolution of sulphurous acid and the distilled products that come over between 190° and 230° C. (374° to 536° F.) are also strongly impregnated with it. This is produced by the decomposition of the sulphur compounds in the kerosene, which are produced by the reaction of the crude distillate with the concentrated sulphuric acid, with which the American kerosene is imperfectly purified. He summarizes his results obtained from the three Standard oils as follows:

14.4 per cent. light inflammable essence.

45.9 per cent. really good burning oil.

39.7 per cent. heavy oil.

2. *Astral oil* or so called, "150° fire test," specific gravity 0.783, flashing point 48° C. (118° F.), burning point 51° C. (124° F.). Shaken with an equal quantity of concentrated sulphuric acid it is colored a golden yellow. Tension of vapor after Salleron, 5^{mm} at 35°. The distilled products were:

Temperature.	Per cent.	Specific gravity.	Burning point.	
Deg. F.		*Deg. B.*	*Deg. C.*	*Deg. F.*
(*a*) Under 150	2.2	....	16	(62)
(*b*) 150 to 170	13.5	0.758 = 55½	29	(85)
(*c*) 170 to 190	21.3	0.768 = 52	43	(110)
(*d*) 190 to 210	18.8	0.777 = 50	57	(133)
(*e*) 210 to 230	15.0	0.786 = 48	75	(167)
(*f*) 230 to 250	10.0	0.795 = 46	99	(210)
(*g*) 250 to 270	9.2	0.806 = 44½	111	(231)
(*h*) 270 to 290	4.8	0.813 = 42	....	....
(*i*) Residue....	5.2	0.834 = 38	....	....

The distillation was entirely destitute of any deleterious odor, and the distillate was normal throughout. He summarizes his results as follows:

2.2 per cent. light inflammable essence.

87.8 per cent. good normal burning oil.

10 per cent. heavy oil.

The results that he obtained from the examination of the Imperial oil (Kaiseröl) of Aug. Korff of Bremen, were nearly identical with those obtained from the astral oil, and his examination of the several samples of Russian oil showed them to be of very fair average quality. (*a*)

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a See page 180. A better method of conducting a research of this character is to use alembics instead of retorts; 200 cubic centimeters in an 8-ounce alembic will yield 1 per cent. for every 2 cubic centimeters of distillate. If the distillate is received into a narrow measuring jar graduated to one-half cubic centimeters, the measuring can be made to one-fourth per cent. without difficulty.

The point in this discussion emphasized by this research is to be sought in the character of the 14.4 per cent. of distillate obtained from the American kerosenes below 150°, having a specific gravity of 59° B. and burning at 62° F. This naphtha, more dense than average benzine, when mixed with a residue containing oils more dense than those found in the astral oil, produces an oil flashing at 78° and burning at 86°, an extremely dangerous oil if no consideration were made of the large content of sulphur compounds revealed upon distillation. These kerosenes were *cracked oils*, not mixed "tops and bottoms", as the English oil merchants have styled them, but a cracked product that was run for a given specific gravity (0.795, equal to 46° B.) and color, without much regard to test, and none at all for other considerations. While there are, no doubt, occasional instances in which retail dealers have mixed naphtha with good kerosene for purposes of fraudulent adulteration, I do not believe that oils are thus prepared by either wholesale dealers or manufacturers. It is, however, not to be denied that the temptation is very great for manufacturers to allow too large a proportion of benzine for safety to run into an oil designed for a market where there are no laws prohibiting the sale of such substances. It is more probable that these kerosenes were made, as Dr. Biel received them, by cracking the heavy residue from which the normal burning oil had been previously removed, a part of which had been cracked too much and the remainder too little, than that the heavy and light residues, once separated, had been mixed together.

Dr. Chandler is at some pains to show that a cost of a few cents per gallon will remove the naphtha from dangerous kerosene. When kerosene sells at wholesale for less than seven cents a gallon, a few cents a gallon would be a large per cent. of its value. *What per cent.* of the present price of refined petroleum would be required to place all of the oils sold at a flash test of 100° F., and of good quality as regards color and sulphur compounds, I am not able to say. I have not the least doubt, however, that it is quite impossible to convert Bradford oil, with all its paraffine, into illuminating oil of good quality in *all respects* by one distillation and one treatment unless the whole distillate below 60° B. is run into burning oil. I am quite certain that it is impossible to crack the heavy residue from which the normal burning oil that exists in the petroleum has been run off and produce a good oil by one distillation and one treatment, nor do I believe that such an oil can be made safe, that is, with a *flash* test of 100°. The question of how much additional expense would be involved in rendering oils prepared by one distillation safe involves quite a radical change in the manufacture of these oils; a change that would, of necessity, increase the cost of the oils, and would, therefore, have to become universal, but which would not necessarily render the manufacturer's profit less certain. At the same time it would improve the quality of the oils to the manifest advantage of the consumer in respect to safety, health, and economy. That poor oils are not safe has been fully proved; that they are not healthful is as clearly proved by the vapors of sulphurous acid and the products of imperfect combustion from crusted wicks and imperfect flow of the oil. Dr. Beil says, when commenting upon the three samples of American kerosene examined by him:

> It is apparent that a kerosene containing such a quantity of heavy oil, and that in addition to this is contaminated by tarry substances containing sulphur, cannot possibly satisfy the demands of the public. While the heavy oils are not in a condition to ascend to the flame in sufficient quantity, the carbonized tarry substances obstruct the wick and prevent the further ascent of the kerosene to the flame. (*a*)

That they are not economical is further shown by the research of Dr. Beil, in which the illuminating power of these common oils is compared with astral oil with the following result:

ILLUMINATING POWER AT A LEVEL DISTANCE OF—

	6^{cm}.	9^{cm}.	12^{cm}.	14^{cm}.
Standard	7	3.35	1.36	0.80
Astral	7	4.50	3.00	1.36
Imperial	7	6.00	3.00	1.36
Russian	(*o*) 7	6.25	4.45	3.70
Russian	(*a*) 7	5.20	4.00	3.00
Russian	(*b*) 7	5.70	3.20	1.65
Russian	(*c*) 7	....	....	....

At 6^{cm} the oils are equal; at 9^{cm} the astral oil is 34 per cent. better than the kerosene; at 12^{cm} the astral is 120 per cent. better than the kerosene; and at 14^{cm}. the astral is 70 per cent. better than the kerosene. The average value of the astral for that distance above that of the kerosene is 27½ per cent. In addition to the inferior illuminating power of these inferior oils we have the fact that they are consumed more rapidly. I am not aware that any exact determinations have been made respecting the comparative rapidity with which equal quantities of these oils are consumed, but it is undoubtedly a fact that oils containing a large proportion of benzine are consumed much more rapidly than those that consist of what Dr. Biel calls "normal burning oils".

I am informed that the demand for "high-test" oils is not equal to the amount that can be made from the petroleum manufactured. Manufacturers the world over can only make what they can sell, and the ignorant and

a Dingler, ccxxxii, 357.

reckless buy the cheapest oil, regardless of all other considerations, encouraging the production of these cheap oils. It is here that intelligent legislation is required, to protect the ignorant purchaser on the one hand, and the honest manufacturer from unprincipled competition on the other, as well as the innocent public, especially prominent as women and children, from the consequences that follow the use of dangerous oils; not safe even with patent "safety lamps". As Dr. Chandler said ten years ago:

It is not possible to make gasoline, naphtha, or benzine safe by any addition that can be made to it. Nor is any oil safe that can be set on fire at the ordinary temperature of the air. * * * Even when the "safety lamp" has an ally in the form of a "safety can", it still fails to make naphtha safe. It is an axiom that *no lamp is safe with dangerous oil, and every lamp is safe with safe oil.* * * * What we want is *safe oil; with it all lamps will be safe.* (*a*)

This axiom expresses a permanent truth. The legitimate use of naphtha for illuminating purposes will be further discussed in Chapter III.

Referring to page 218, it will be observed that Dr. Chandler concludes, from his experiments upon the temperature of the oil in burning lamps, that "it is apparent that 100° F. is too low a standard for safety; 120° F. would not be too high a standard".

While it cannot be denied that these conclusions are correct as indicating a standard of absolute safety, it will be observed that in these experiments the extreme temperature of oil in glass lamps was 98°, being never over 8° above the temperature of the room. The higher temperatures were in metallic lamps, in which the oil reached 27°, and in one instance 39° above the temperature of the room, the exceptional temperature being reached by student-lamp No. 24. Metallic lamps are widely but not generally used, and student-lamps are so constructed as to reduce the danger of explosion to a minimum. It therefore appears to me that if legislation strictly required all oil to be brought to a *flash test* of 100° F. the general public would be fairly protected in the legitimate use of such oils, so far as mere legislation alone can afford protection. Such legislation should rigidly exclude all forms of naphtha from use in households, in lamps or in stoves of any pattern whatever, as always, under all circumstances and under whatever name or guise, more dangerous than gunpowder. An oil that will not take fire when thrown from a lamp broken upon a brick floor heated to a temperature of 93° is a safe oil for legitimate use. Floors are rarely heated to that temperature. A temperature to which oil is heated in lamps of *ordinary* construction in a room the atmosphere of which stands at 93° is a safe temperature. An oil that did not reach 100° under the last conditions stated, and that did not take fire under the first conditions stated, flashed at 100°. I therefore conclude that an oil that flashes at 100° F. is a safe oil, and while oils that flash at a higher temperature, and *that cannot be prepared by cracking petroleum by one distillation*, are more safe, healthful, and economical, legislation can hardly require anything further than a reasonable limit of public safety.

SECTION 3.—METHODS OF TESTING PETROLEUM.

I have not been able to ascertain where, when, and by whom the question of safe oils was first agitated. Early in 1861, when I was engaged in examining petroleum in the laboratory of Brown University, Professor N. P. Hill (now Senator Hill, of Colorado) was interested in this subject, and it was with his assistance, if not at his suggestion, that the experiments described in Mr. Allen's paper, previously quoted, were undertaken. The method of conducting the test, as described by Mr. Allen, was at that time supposed to be sufficient, and it is my belief that when undertaken by a careful manipulator, accustomed to the use of apparatus, it is; but it soon after became apparent that in untrained hands this method of manipulating was in many respects deficient. As a result, a large variety of apparatus and of methods have been contrived for testing oils, both in America and in Europe. The following descriptions of several testers, that represent the classes to which they belong, are taken from an elaborate article in the *Sanitary Engineer*, abridged from the article of Messrs. Engler and Haas in the *Zeitschrift für Analytische Chemie*, 1881: (*b*)

Petroleum testers may be divided into two classes, according to the principle upon which they are constructed. In the first class, the vapor expansion of the petroleum is measured at a stated temperature, and from this its combustibility ascertained; while in the second class the temperature is determined at which the oil evolves inflammable vapor. To the first class belongs the apparatus of Salleron-Urbain, which is the most accurate of its kind, and the only one to be described. Most testers belong to the second class, and are known as "opened" or "closed", the latter because the surface of the oil is more or less protected from the atmosphere.

In some countries two points are determined in testing petroleum: the first is that of the temperature at which the liquid begins to give off an inflammable vapor, and is known as the "flashing point"; while the second, or "burning point", is the temperature at which the liquid continues to burn when ignited. Most forms of apparatus are constructed with reference to the determination of the flashing point only, and, as an oil becomes dangerous at the temperature of its flashing point, there is no necessity for a further test.

The flashing point of a petroleum will be found to vary according as the vessel is partly or entirely filled with petroleum, is open or closed, the petroleum is quiet or agitated, whether the air above it is in a large or small volume in relation to the quantity of oil, whether quiet or in motion, whether charged more or less with the vapor evolved from the petroleum, and, above all, as to the distance of the torch from the surface of the oil. It is also necessary to consider the kind and size of the taper used, the length of time it is allowed to remain near the surface of the oil in applying a test, the dimensions and material of the oil-holder, and the rapidity and uniformity of heating. As these conditions vary in different forms of apparatus, the flashing point will be found higher or lower; and even in the same apparatus this may happen, according to the care given to the manipulation in the above respects.

Salleron-Urbain's apparatus, in which the expansion of the vapor of petroleum is determined, is used principally in France. It consists of a copper vessel, A, Fig. 48, in which is fixed the conical pillar D, and which is covered by the plate *d d* fitting on its upper edge. C is a movable plate turning on the pillar D, and held in place by the screw *n*. In this movable plate is the cylindrical chamber

a Am. Chem., iii, 24. *b* Oil and Drug News, 1881.

B, closed at the top by the screw-plug *p*, while its lower opening can be placed in communication with the vessel A by means of the opening *o*, or by turning the plate C it can be sealed by the upper surface of *d*. There are also in the plate *d* a thermometer, a graduated tube *m*, 35^{cm} long, and the regulating apparatus *l*, which consists of the screw *r*, so arranged that by raising or lowering it the water level in *m* is made to stand at zero.

Fifty cubic centimeters of water are put in the vessel A, the plate *d d* and the sliding piece C are screwed down tight by *n* and so placed that the chamber B does not communicate with A. B is nearly filled with the petroleum to be tested, the screw *p* replaced, and the whole placed in warm water until the temperature has become constant. The water level in *m* is placed at zero, and then the plate C is moved until the opening of B comes over the opening *o*. The petroleum spreads upon the surface of the water in A, and by the expansion of its vapor causes the water to rise in the tube *m*, when its height is read. By a comparison of this number with the known expansion of the vapor of normal petroleum at a corresponding temperature the combustibility of the oil is determined. For this purpose a table accompanies the apparatus which gives the obtained vapor expansion of normal petroleum in *m* for different temperatures sought.

This method depends upon the supposition that the numbers which express the expansion of the petroleum vapor run parallel with the temperature of the inflammability of all kinds of petroleum. It has been found, however, that this supposition is not correct for all cases, inasmuch as the presence of a small quantity of a very volatile hydrocarbon occasions, by increased temperature, a correspondingly greater pressure in the tube *m*, without its being sufficient to form an explosive mixture with air. Experiments were made on samples of petroleum prepared by mixing in varying proportions oils of low and high boiling points, and from these experiments it is concluded that a small percentage of a volatile constituent, notwithstanding the equal inflammability of the oils, occasions an uncorresponding increase of the vapor expansion. From this it is evident that while this form of apparatus would give accurate results in some cases, it could not be depended upon in others. They have concluded that oils are to be considered safe that exhibit a tension of 64^{mm} of water at 35° C.

The second class of petroleum testers are designed for the determination of the "flashing point", or temperature at which the oil gives off an inflammable vapor. The majority of testers, and those found most reliable, belong to this class.

The older forms consisted of an open vessel partly or entirely filled with petroleum, and heated until inflammable vapors were formed upon the surface of the oil. These have been improved by placing the petroleum in a closed vessel, by which the conditions of the actual use of the oil in lamps is more nearly attained.

Of the open testers the Tagliabue, the Danish, and the Saybolt are the most important.

Tagliabue's open tester, Fig. 49, was employed in the official testing of petroleum in this country until 1879, and even now it is used in Germany with immaterial changes and under various names. It consists of a brass water-bath A upon the stand B, heated by the lamp C. D is the glass petroleum-holder, in which is immersed the thermometer E. The bath is nearly filled with cold water, allowing for the displacement by the oil holder. D is filled to the top with the petroleum to be tested, care being taken not to wet the rim, the thermometer placed in position, and the lamp lighted. The heating should be gradual, and, if necessary, the lamp be occasionally removed. When the oil has reached the temperature at which you wish to begin the testing, a small flame, either from a wooden splinter or a gas jet, is slowly and carefully passed over the petroleum, about 12^{mm} (nearly half an inch) from its surface. If no flashing takes place, this is repeated as the temperature rises until the flashing point is reached. During testing the apparatus should be protected from draughts of air.

The Danish tester differs from Tagliabue's only in having the petroleum vessel of copper instead of glass, and in being but partly filled with oil.

The Saybolt tester was, in 1879, adopted by the produce exchange of this city in the testing of refined petroleum. It resembles the open tester of Tagliabue, differing only in the use of the electric spark for the burning splinter. It is represented in Fig. 50, and consists of the copper water-bath F, containing the petroleum-holder, which, with the other parts of the apparatus, are placed on the tray C, and for transportation can be inclosed in the box A. D D are the covers of two battery elements. H is a current breaker, E an induction coil, and *e e* the conducting wires for producing the spark over the surface of the petroleum. *a* is the thermometer of the oil-holder, and a^1 that of the water-bath.

In using this apparatus the bath is filled with water and heated to 100° F., after which the lamp is removed. The oil-cup, filled to within 3^{mm} ($\frac{1}{8}$ of an inch) of the top with the petroleum to be tested, is placed in the bath and the thermometer immersed in the oil until the bulb is just covered. As the temperature of the oil is raised to 90° F., produce a spark by the key H, and after replacing the lamp repeat this operation every two or three degrees until the flashing point is reached.

The apparatus of Abel, represented in Fig. 51, is employed in England in determining the flashing point of petroleum. It consists of the copper cylindrical vessel D, in which is the water-bath, composed of the two copper cylinders B B and C C, the latter resting on the ring *g g* and covered by the plate K K; *f* is a funnel for filling the water-bath, and *e* is the thermometer placed in it.

The brass petroleum-holder A rests in an ebony ring fixed in the plate K, and hangs in the air-filled space H of the water-bath. It is provided with a closely-fitting cover, through which passes the thermometer *b*, and upon which is placed the small oil-lamp *c*, movable upon the horizontal axis. There are also in the cover three rectangular openings, which can be opened and closed by the sliding bar *d*, by the movement of which the lamp is so tipped that its nose comes opposite to the opening in the middle of the cover.

The oil-lamp can be replaced by a gas flame, which is much cleaner, and was used in the experiments with this apparatus.

The water-bath is filled and heated to 54° C. A is then filled to the mark *a* with the petroleum to be tested, covered and placed in the space H. The wick of the lamp is arranged to give a flame 4^{mm} long. When the temperature, by the thermometer *b*, has risen to 19° C., the tests are commenced, and repeated every degree or two until the flashing point is reached. In testing very volatile oils the air-space H should be filled with cold water, and in the testing of oils of high flashing point this water should be heated to about 50° C.

In closed petroleum testers the oil is heated in a closed vessel until inflammable vapors rise from the oil into the empty part of the holder. There are a large number of these testers; among them those of Tagliabue, Abel, Sintenis, Parrish, Bernstein, and others.

The Tagliabue closed tester is represented in Fig. 52, and consists of the water-bath A and the petroleum holder B, both of brass. The latter is provided with a cover, upon which are fixed the hood C, containing a rectangular opening *a*, the sliding bar *b*, for opening or closing the aperture beneath it, and lastly the thermometer D.

There is also an improved form of this tester differing from the first in the arrangement of the cover, which is shown in Fig. 53. In this *a a* is the cover, with openings under the movable bar *b b*, by which they are closed; *f f* are small openings in *b b*, closed by the piece *e*, held up by the spring beneath it. By pressing upon the knob *c* the apertures *f f* are opened, and the bar *b b* can be moved by the handle *g*.

In using the apparatus, the water-bath and oil-holder are filled and the bath gradually heated by the spirit-lamp. When the thermometer reaches a definite temperature a small flame is introduced through the opening *a* into the hood C; and at the same time the bar *b*, in Fig. 52, is moved to one side, or, as represented in Fig. 53, the knob *c* is pressed down, in order to establish communication with the air by openings *b* or *f f*. This testing is repeated as the temperature rises until the flashing point is reached.

The next petroleum tester to be noticed is the Parrish naphthometer. It is used chiefly in Holland, and differs from those already described in that the inflammable mixture is carried out of the petroleum holder to a stationary flame. It is represented in Fig. 54, in

which A is the tin oil-holder, C the water-bath, D the support, and E the lamp. The holder is provided with a projecting cover, in which is the cylinder *d*, having in its axis a small tube, with a wick running into the petroleum. *e* is a screen, against whose base rests the glass plate *f* for protecting the thermometer from the heat of the wick flame, and lastly B is a chamber communicating with the air, in which are the openings *a* and *b b*, the former for the circulation of the air through the petroleum-holder, and the latter to allow the passage of the oil from B into A. The thermometer *c* is placed in the vessel B.

The bath is filled with cold water, and the oil-holder with the petroleum to be tested, to a point 1^{cm} below the rim. The heating must be slow and effected by the spirit-lamp, whose flame is only 1 to 1.5^{cm} high. The small wick in *d* is then lighted, care being taken that the flame is not more than 6 to 7^{mm} high. The heat of this flame produces a current of air, which, coming in through the opening *a*, spreads over the surface of the oil and passes out by the tube *d*, taking with it the vapors evolved from the heated oil. When the oil vapors are sufficient in amount to produce an inflammable mixture, they are ignited by the flame in *d*, the flame being extinguished by the sudden motion of the air At this moment the flashing temperature is read.

The apparatus devised by Engler is of the closed form, to which is added an electric mechanism similar to that of the Saybolt tester. It is shown in Figs. 55 and 56, and consists of the copper water-bath A, heated by the spirit-lamp B. C C is a glass vessel for water, which has a filling mark etched upon it; *m m* is the cover, and *n* the thermometer. In the cover is the glass petroleum vessel D, also provided with a filling mark, and to which is fitted the brass cover *o o*. The latter is shown in Fig. 56, in which will be noticed the following details: *s s* are two movable covers, *t t* the conducting wires, insulated by the ebony rings *u u*, *r* the thermometer, and *q* the handle of the stirrer *p*, seen in Fig. 55. The conducting wires terminate in platinum points in the vessel D, from ½ to $\frac{3}{4}^{cm}$ above the surface of the oil, and at a distance of 1^{mm} from each other. For the production of the electric spark a chromate cell is used, with an induction apparatus which gives a spark at least 2 to 3^{mm}. long. The electric apparatus of the Saybolt tester answers very well. In using this tester the baths A and C are filled with water, and D is filled to the mark with the oil to be tested. When the petroleum vessel is in place the water in C should stand 1^{cm} below the rim. The wires are connected with the induction coil and the lamp lighted. As the temperature rises to the testing point the spark is passed every degree, care being taken that the spark continues from one-half to one second. After each passage of the spark the oil is gently agitated by the stirrer. The operation is continued in this way until an explosion occurs, by which the covers *s s* are thrown open.

The difficulties that have been found to attend the construction of an apparatus that in every one's hands should give uniform results have been considerable. In the experiments of Engler and Haas three kinds of petroleum were employed in testing the various forms of apparatus, and at the start the flashing point of each oil was carefully determined in a closed apparatus.

Sample A flashed at .... 22° C. = 71.6° F.
Sample B flashed at .... 29° C. = 84.2° F.
Sample C flashed at .... 40° C. = 104° F.

The following table shows the temperatures at which they flashed in the testers named:

Tester.	A.	B.	C.
	Deg. C.	*Deg. C.*	*Deg. C.*
Tagliabue, open	22.7 to 38.8	32.2 to 48.8	45.5 to 57.2
Danish	19.5 to 21.0	29.0 to 31.0	42.0 to 45.0
Saybolt	30.6 to 31.7	36.1 to 36.6	48.8 to 52.7
Tagliabue, closed	.....	24.0 to 39.4	.....
Abel	16.0 to 17.1	22.2 to 23.8	32.4 to 33.8
Parrish	20.7 to 23.0	25.5 to 30.7	36.5 to 39.0
Engler	21.0 to 22.5	28.0 to 30.5	39.3 to 39.7

The average of the several tests with the different instruments on the same samples are given in the following table:

Testers.	No. of tests.	Average.	Variation.
		Deg. C.	*Deg. C.*
Tagliabue, open	A 6	30.95	16.1
	B 9	42.00	16.6
	C 6	52.20	13.3
Danish, open	A 5	20.80	3.5
	B 4	30.00	2.0
	C 4	43.25	3.0
Saybolt, open	A 4	31.30	1.1
	B 2	36.35	0.5
	C 2	50.75	3.9
Tagliabue, closed	B 18	31.68	15.4
Abel, closed	A 4	16.60	1.1
	B 7	22.64	1.6
	C 3	32.96	1.8
Parrish, closed	A 5	21.40	2.7
	B 15	27.30	5.2
	C 9	37.70	2.5
Engler, closed	A 4	21.95	1.5
	B 19	29.40	2.5
	C 2	39.50	0.4

The great variation in the results given by Tagliabue's open tester were due to a variation in the height at which the flame was passed above the oil, and the temperatures indicate different heights, from 1^{mm} (0.04 of an inch) to 12^{mm} (0.47 of an inch).

The uniformity of the results furnished by Engler's apparatus upon sample B, where eleven out of nineteen tests were within a variation of 1° C. and sixteen out of nineteen tests were within 1.5° C., is quite remarkable, and shows that this apparatus is greatly superior to most of the others in this respect.

By the use of the double water-bath and the stirrer the heating is slow and regular, and, so far as possible, is independent of the size of the heating flame. Moreover, by the use of the electric spark, the size, intensity, and distance of the igniting agent is always the same, and in consequence of its short duration no vapor formation is noticeable. Finally, the form of this tester is such that the conditions maintained in its use closely resemble those which are found to exist in petroleum lamps. Herr Victor Meyer is of the opinion that, in the use of the ordinary petroleum testers, the true or absolute flashing temperature of the oil is not found, but a temperature higher or lower than the one sought, depending upon the capacity of the various forms of apparatus and the quantity of petroleum employed. The progress recommended consists in putting about 40 cubic centimeters of the petroleum in a glass cylinder of about 200 cubic centimeters capacity, and placing this in a vessel of warm water until the petroleum has reached the testing temperature. The cylinder is then removed, and the oil well shaken; after which a test is made by means of a gas flame, to see if the oil can be lighted. It is clear that in this process we obtain a constant maximum of the saturation of the oil with petroleum vapor corresponding to the prevailing temperature.

In this country the open tester of Tagliabue was at first in general use, and later his closed tester. The New York produce exchange has, within a few years, adopted Saybolt's. In England and Canada Abel's has been adopted; in France both open and closed testers, particularly the tester of M. Granier, has been used, as well as the apparatus of Salleron Urbain; in Holland the naphthometer of Parrish; and in Russia, and also in Germany, some of the open testers have been employed.

It is manifest that the great difference in the results given by these instruments, included between 22.64° C. and 42° C., when made by the same person on the same oil, indicates that a decision should first be had in respect to the instrument used before the temperature should be determined at which an oil is considered safe.

I think that more attention has been paid to this subject in England than in this country, or it would perhaps be more proper to say that in England the subject has received consideration in a manner that has produced more satisfactory results. There legislation has been national; here it has been local. There the subject was placed in the hands of eminent scientific men, and legislation was had in 1868 based upon the results of their labors. This legislation described the instrument and the manner of testing, and fixed the test at a flash at 100° F. After a trial of two years, during which numerous criticisms were found to lie against the provisions of the law, Professor F. Crace Calvert subjected the working of the apparatus under the act to very careful examination, and concluded (*a*) that—

These results show the influence of time in raising six samples of petroleum spirits from 52° F. to their flashing points. Thus, when fifteen or twenty minutes are employed, the whole of the six samples tested could not be called "petroleum", according to the act of 1868; the owner would be liable to a penalty and the loss of the fluids, whilst if the time employed to heat the liquid is half an hour they would all be considered petroleums, their flashing points being above 100° F.

His results are given below:

FLASHING POINT.

No. of sample.	Time, 15 minutes.	Time, 20 minutes.	Time, 30 minutes.
	Deg. F.	*Deg. F.*	*Deg. F.*
1	96	98	102
2	92	99	101
3	90	98	101
4	94	96	104
5	96	98	110
6	95	99	108

He further remarks on this point:

I am therefore of opinion that as the act has been made to protect the public from fire and explosions resulting from the employment of too highly inflammable hydrocarbons, the chemist or person called upon to test liquids of this class should raise the temperature of the fluids as quickly as possible; otherwise they favor the vendor and manufacturer, to the detriment of the consumer.

The next series of experiments was made with a view of corroborating a statement made by Mr. Norman Tate, viz, if two thermometers are placed in the petroleum spirit, one, as indicated in the act, 1½ inches below the surface of the liquid, the other being only one-half inch below the surface, a difference of several degrees will be noticed between them at the time the vapors will flash. * * * The following results confirm Mr. Tate's observations:

	Flashed at—	Flashed at—
No. 4	94° F. 1½ inches.	99° F. ½ inch.
No. 5	94° F. 1½ inches.	98° F. ½ inch.
No. 6	95° F. 1½ inches.	99° F. ½ inch.

This curious and unusual fact is due, in my opinion, to this: that petroleum not being a homogeneous liquid, but a mixture of several hydrocarbons, the highest products being first expelled, the heat rises toward the surface, and in this way the difference in temperature referred to is produced.

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a *Jour. Soc. Arts*, xviii, 290.

After suggesting a remedy for these difficulties Professor Calvert closes his article as follows:

From the above experiments the following conclusions may be drawn, viz, that the petroleum act of 1868 does not give sufficient and precise instruction for testing petroleum spirit; therefore it is to be hoped that government will take the matter in hand and do away with the objections to the present act, substituting more clearly defined rules and instructions, so as to enable the operator to determine the flashing point of petroleum spirit with greater accuracy.

This subject was again very fully discussed by Mr. Boverton Redwood, secretary of the Petroleum Association of London, in 1875, (*a*) in a letter to the *English Mechanic and World of Science*, in which he gives a very excellent popular description of the manner of testing petroleum under the petroleum act then in force.

In July, 1875, the Secretary of State for the Home Department requested Professor F. A. Abel, chemist to the War Department, to report on certain points relating to the method of testing petroleum as prescribed in Schedule 1 of the petroleum act, 1871. In accordance with this request he submitted his report, dated August 12, 1876. Before commencing his investigations he consulted, among others, the late Dr. H. Letheby, Dr. J. Attfield, Dr. B. H. Paul, and Mr. Boverton Redwood, representing with himself an unsurpassed array of talent and experience with reference to this subject. I quote here this report entire as representing the most complete and intelligent discussion of this subject extant, based upon a most exhaustive scientific research, and confirmed by comparative tests in such a manner as to make it a model for a basis of intelligent legislation.

REPORT TO THE SECRETARY OF STATE FOR THE HOME DEPARTMENT ON THE SUBJECT OF THE TESTING OF PETROLEUM.

In compliance with the request of the Secretary of State for the Home Department, as conveyed by Home Office letter, dated July 7, 1875, 1,386, 61 a, Appendix V, that I should report on certain points relating to the method of testing petroleum as prescribed in Schedule 1 of the Petroleum Act, 1871, I now submit the following statements and the conclusions at which I have arrived respecting the points specially submitted for my consideration in the letter above referred to:

I.

With reference to the merits of the method of testing petroleum at present prescribed.

In the evidence taken before a Select Committee of the House of Lords in 1872, the relative merits of and the relation existing between the open flashing test which is prescribed in the existing petroleum act and a modified flashing test, called the "close test", which it was proposed to substitute for the former, were discussed by a number of witnesses.

The opinions expressed and the experimental data upon which the opinions were based were in several respects very conflicting.

The statements of a great majority of the witnesses were, however, in accord with regard to the unsatisfactory or fallacious nature of the open flashing test as laid down in the existing Petroleum Act.

The important objection raised against the open test is, that it is liable to "manipulation", *i. e.*, that in consequence of certain very readily variable elements in the details of the test (added to the interfering action of even slight currents of air) the flashing point of one and the same sample of oil may be made to differ many degrees in the hands of different operators (or of one and the same operator at different times).

The majority of witnesses also were agreed in the opinion that the proposed "close test" was decidedly more reliable in itself and much less open to manipulation than the open test. The differences of opinion with regard to it were almost entirely confined to the necessity for some modifications in its details and to the relation which the results furnished by it bear to those obtained with the open test, or, in other words, the particular temperature which in dealing with the "close test" should be held to correspond to the standard or "flashing point" (100° Fahrenheit), fixed in the existing act as applied to the open test prescribed. On the latter point a very considerable difference of opinion existed between two sections of witnesses; on the one hand, the results of a number of experiments made by several witnesses with the close and open tests were adduced in support of the conclusion that a flashing point of 85° given by the close test should be accepted as equivalent to 100° by the open test, while on the other hand similarly strong testimony and extensive experiment supported the view that the standard flashing point for the close test (equivalent to 100°) should not be higher than 75°.

These differences of opinion were obviously ascribable, in great measure, to the unreliableness of the present (open) test, and also to certain variable points in the details of the "close test", which tend to allow of the results furnished by this test being also regulated (though not nearly to the same extent as with the open test) by small variations in the *modus operandi* adopted by different experimenters.

The opinion which I myself had formed from the results of practical experience in the employment of the flashing test, as prescribed in the schedule of the existing act, was quite in accordance with the general opinion of the witnesses examined before the House of Lords committee as to its untrustworthiness. Moreover, after careful consideration of the subject, it appeared to me, to say the least, very doubtful whether certain sources of errror could by any modification of the arrangements and directions laid down in the schedule of the existing act be eliminated to such an extent as greatly to reduce the liability of the test to furnish results not fairly comparative with each other, and its susceptibility to "manipulation" or regulation in the hands of different experimenters.

Before proceeding to examine into the merits and defects of the proposed "close test", and to endeavor to supply the want of a generally satisfactory test (either by a modification of one of the known tests or by elaboration of some new method of experimenting), I considered it desirable to ascertain whether the additional experience of the last three years had led some of the principal witnesses and others who had given attention to this subject to modify the views expressed at that time or to form any decided opinion as to the direction in which a satisfactory solution of the difficulties connected with the present system of testing might be sought.

I therefore addressed circular letters (Appendix I) to the following:

Mr. T. W. Keates, consulting chemist of the Metropolitan Board of Works.
The late Dr. H. Letheby.
Dr. J. Attfield.
Mr. Dugald Campbell.
Dr. B. H. Paul.

a English Mechanic and World of Science, xxii, 355.

The secretary of the Petroleum Association.

The secretary of the Scottish Mineral Oil Association.

The local authorities under the act at Liverpool and Bristol.

As the replies to my communications, which I received from several of the above, embody the present views entertained with regard to the test prescribed by the existing act and the points which require consideration in the attempt to provide a satisfactory test, I consider it advisable to give the following précis of such replies.

Mr. Keates says: "The present test fails by the nature of the test itself; it is not possible to preclude sources of inaccuracy in its use." He proceeds to point out that a considerable difference in results may arise with different operators, working with the utmost honesty of purpose according to the interpretation put upon the directions of the schedule of the act (as to rate of heating, application of test flame, etc.), but that "such differences are trifling as compared with those which can be obtained when there is a desire to get away from the truth", such differences being always in one direction, viz, in postponing the time at which the ignition of the vapor takes place. He proceeds: "I think it is conceded that the present open test is fallacious, and that it can be made to give different results by different operators, according to the wish or intention of such operator." Mr. Keates then dwells upon the merits of the close test, the adaptation of which he had advocated in 1872, and says: "With a proper regulation as to the application of the light to the vapor chamber very close agreement can be obtained, and I do not think the test is capable of manipulation." He expresses his belief that the close test is not objected to *per se*, but that the point upon which great difference of opinion exists is the difference to be made in the parliamentary standard of temperature if the close test be substituted for the open test, which was the main point of dispute in 1872.

The late Dr. Letheby stated that the difficulties in the way of obtaining trustworthy results with the present (open) test, applied "according to the spirit" of the instructions laid down, are manifold, arising in some cases from the faulty construction of the apparatus, in others from the erroneous method of working, and in others from the indefinite nature of the instructions." After discussing the difficulties included under these three heads, and pointing out that the instructions originally laid down by him, Dr. Attfield and myself, in 1869, embody most of the improvements and alterations required to make the present test more certain and satisfactory. Dr. Letheby proceeds to say that, "considering an open test must, under any circumstances, be uncertain, because of the diffusion of the petroleum vapor into the atmosphere," he thinks "a closed test would be more satisfactory", and that the only difficulty is the point at which the legal standard of temperature should be fixed. As regards this standard, he differs considerably from Mr. Keates, and in support of his view refers to experiments made by himself and Mr. Dugald Campbell (and confirmed by Mr. Norman Tate and Dr. Robinson), which were quoted in the evidence given before the House of Lords committee.

Dr. Attfield simply expresses the opinion that nothing short of an original investigation will lead to a satisfactory solution of the difficulties connected with the test.

Mr. Dugald Campbell discusses in detail the defects in the instructions laid down for the use of the present test, and which he regards as giving rise to the discrepancies occurring in the application of the test. He considers, from the results of his own experience, that if certain points, which he details in connection with the application of the open test, be adhered to, "independent experimenters would not *materially* differ in their results." Mr. Campbell's experience with the close test does not lead him to form so favorable an opinion of it as is entertained by Mr. Keates, but he considers that "with strictly defined rules for applying the test", which are carefully carried out, the results furnished by it "are likely, on the whole, to be rather more uniform than with the open test". He considers that some modifications in the construction of and mode of working with the close test as described in 1872 are necessary, and is in accordance with Dr. Letheby regarding the standard temperature which should be adopted with the close test (as equivalent to 100° with the open test).

Mr. B. Redwood, the secretary of the committee of the Petroleum Association, in expressing the views of that committee, considers that the difficulties which have arisen in the application of the present test are due to a "want of detail in the parliamentary directions for applying the test, and to the delicacy of the test or liability to uncertainty in the hands of unskillful operators". The committee consider that if directions with regard to the rate and uniformity of heating the apparatus, and of the size and character of the flame used for testing, had been strictly laid down, "the results of different operators would have *approximated* more closely, and that with *skilled persons* the results would have been *sufficiently uniform* to have given satisfaction. Inasmuch, however, as the inspectors under the act are men whose training has not qualified them to perform operations involving close details of manipulation, the committee are driven to the conclusion that the present test, even with such amended instructions for its use as have been instanced, would be found too delicate."

In discussing the directions which should be taken for providing a better test, stress is laid upon the desirability of adopting a system of testing which would preserve the existing standard of 100°, as the public, having been "educated in the belief that anything over 100° Fahrenheit means safety and below 100° danger, might associate any lowering of the standard with increased risk to themselves even if such lower standard were explained to be equivalent to an equally stringent and more certain test".

Mr. Redwood proceeds to consider the directions in which, failing the possibility of an efficient modification of the existing open test, another test might possibly be sought, and considers, with reference to these, that—

(*a*) The American or fire test (which consists in determining the temperature at which the surface of the heated petroleum takes fire permanently) is as open to discrepancies as the present legal test.

(*b*) The automatic tests which have been proposed (depending for their action upon the vapor traveling to a fixed distance and there becoming ignited) are too complicated for general use, and have not given encouraging results.

(*c*) The close test involves a lowering of the standard flashing point, and is therefore objectionable.

The committee of the Petroleum Association state their opinion through Mr. Redwood, that if it should not be possible to modify the open test so as, while preserving the present standard, to reduce its delicacy sufficiently to allow of its satisfactory employment "by an inspector of average intelligence", "the closed test would appear to be the best substitute, but would, of course, necessitate a reduction of the standard," in consequence of which "the prejudice created in the mind of the public would have to be combated". In the event of my deciding in favor of the close test, the committee refer me to Mr. Redwood's evidence before the House of Lords committee in 1872, in which he agrees with Dr. Letheby and Mr. Dugald Campbell regarding the standard temperature to be adopted in connection with this test as equivalent to the present legal standard of 100°.

In conclusion, the committee request that Mr. Redwood may be allowed to exhibit to me the precise method adopted by the Petroleum Association in testing the petroleum imported into London.

The Liverpool Petroleum Association expresses their concurrence in the statements submitted by Mr. B. Redwood, as secretary of the Petroleum Association.

The Local Government Board of Bristol adopt the views expressed by the representative of the petroleum trade in Bristol, Mr. F. F. Fox, to whom they referred my letter of inquiry, and who suggests that, "following the example" of the Petroleum Association of London, the object aimed at should be "such an improvement of the existing test as shall take away (if possible) its present imperfections, or, failing this, the adoption of the closed vessel, provided an equivalent standard be fixed".

The secretary of the Scottish Mineral Oil Association is desired to state that the directions, as detailed in the existing act, are much too indefinite, and that the test is subject to extraneous influences which produce discrepancies in the results of even conscientious and careful chemists. The association considers it desirable to have a testing apparatus, the range of variations of which cannot, under any circumstances, be more than two or three degrees, and that the close test is the most satisfactory and reliable one that can be adopted. Such an apparatus as was described in the proposed bill of 1872 is believed to meet the views of every one, and is certainly the most accurate test which has had the attention of the association. It should, however, be distinctly stated, with reference to this close-test apparatus, "that the movable cover for the circular opening should be removed only when the light is being applied, and immediately replaced if no flash be produced."

From the foregoing précis will be seen—

(1.) That the authorities quoted are agreed in regard to the unsatisfactory nature of the existing method of testing petroleum, as prescribed in Schedule 1 of the Petroleum Act, 1871.

(2.) That they are also in accord as to the great difficulty, if not impossibility, of modifying the existing "open test" so as to render it capable of uniformly insuring reliable and satisfactory results in the hands of different operators.

(3.) That the close-vessel test, which it was proposed to prescribe in the contemplated act of 1872, is more satisfactory than the present open test; but—

(4.) That differences of opinion exist with regard to the relation which the results furnished by this "close test" bear to the present open test; and—

(5.) That there are evidently some points of uncertainty connected with the proposed "close test" which render it also liable to furnish different results in the hands of different operators.

The results of my own experience with the present legal test, and a careful examination into the various points raised in the foregoing with regard to it, and to the "close test" which it has been proposed to adopt as a more trustworthy test, led me to the following conclusions:

(*a*) That the method of testing petroleum prescribed in Schedule I of the Petroleum Act, 1871 (34 and 35 Vict., cap. 105), is not of such a nature as "uniformly to insure reliable and satisfactory results".

(*b*) That the "close test", which it was proposed in 1872 to substitute for the existing "open test", and which was discussed in the evidence taken before a select committee of the House of Lords in session in 1872, though more satisfactory, is open to objection on several grounds, and is liable to furnish different results in the hands of different operators.

II.

With reference to the alterations in method of testing petroleum which should be adopted to secure reliable and satisfactory results.

In addressing myself to the preparation of a reply to the second point submitted for my consideration in the letter addressed to me by the Under Secretary of State for the Home Department, I proceeded, in the first instance, to consider whether it was possible to devise some method of testing differing entirely from either of those which have been referred to, and which would be likely to prove satisfactory, as being sufficiently simple, certain, and free from liability to involuntary or intentional modification in the hands of different operators. My examination into the merits of some automatic tests which have been proposed, and a trial of one or two other plans which suggested themselves, for comparing the volatility of samples of petroleum by operations placed more or less beyond power of control by the manipulator were not attended by promising results.

The possibility of modifying the present legal test (the open test), so as to reduce within satisfactory limits the existing sources of discrepancy, next received a most careful consideration by me; but I came to the conclusion that, supposing directions could be laid down or arrangements contrived for securing uniformity in the rate of heating the oil to be tested, in the temperature at which the operation of testing is commenced, and in the nature and mode of applying the test flame, one great source of uncertainty inherent in the test—namely, the free exposure to the air of the surface of the oil from which the vapor is evolved—would still remain.

At the suggestion of Mr. Boverton Redwood I witnessed some testing operations conducted with the open test, but with the employment, in place of the ordinary thermometer, of an ingenious combination of a thermometer and clockwork, devised by Mr. R. P. Wilson (*a*) (and called by him a chrono-thermometer), the stem of the thermometer being made, with its scale, to form a circular frame, surrounding a dial with clockwork. The object attained by this arrangement is to ascertain readily that the rate of heating is in accordance with any prescribed regulation, the hands of the clock being made to keep time with the rise of the thermometer. The same result is, of course, attainable in ordinary practice by having a timepiece in close proximity to the test apparatus, so that it may be watched at the same time as the thermometer and the rate of rise of the latter regulated accordingly. The employment of Mr. Wilson's arrangement is certainly more convenient than having to watch the thermometer and timepiece separately; but it adds a somewhat expensive item to the apparatus, and, supposing that by its employment uniformity in the rate of heating could be secured, only one element of uncertainty in the existing test would then be avoided.

The general concurrence in the comparatively satisfactory nature of the "close test" led me to consider next whether it might not be possible to remove the points of uncertainty involved in the employment of that test by different operators. The chief variable points connected with it are—

(1.) The rate of heating of the apparatus.

(2.) The nature of the test flame to be used.

(3.) The precise position in which the test flame is to be applied, and the duration and frequency of its application.

Considerable differences of opinion were expressed by experts in their examination before the House of Lords committee as to the rate of heating which should be adopted in the application of the open test, differences of opinion which apply equally to the "close test".

Having carefully considered this point, I have come to the conclusion that it is unimportant whether the rate of heating be 1° or 2° per minute or 20° in fifteen minutes (the three rates insisted upon by different witnesses in the evidence), or whether a decidedly different rate of heating be adopted, provided the source of heat and amount of heat employed, and the mode of applying it, be the same in all cases, such definite rules being laid down with respect to this, and such precautions being taken in the construction of the apparatus, as to render the attainment of uniformity by different operators simple and certain.

The suggestion to apply hot water as the source of heat in connection with a flashing test was made by one of the House of Lords committee in 1872, and Mr. Keates stated that this subject had received consideration, but that decided objections had been advanced against this mode of heating. Being strongly of opinion that hot water presented the only simple means of securing uniformity in the

a Described in *English Mechanic and World of Science*, xxii, 496.

rate of heating, I made many experiments, with a view of attaining, by simple arrangements, a satisfactory rate of heating by its means, which should be uniform with different apparatus of uniform construction and dimensions. By inclosing the hot-water vessel in an air chamber (or a jacket with intervening air-space), and by interposing an air-space between the hot water and the receptacle for the petroleum, I succeeded, on the one hand, in satisfactorily retarding loss of heat by radiation, and, on the other hand, in securing a sufficiently gradual transmission of heat to the petroleum. The rate of transmission of heat is not uniform throughout all periods of one single operation, but it is uniform at the same periods in different operations, and the average rate of heating is uniform. At the commencement, when the petroleum is cold and the water at its maximum heat, the rate of heating is necessarily most rapid, while as the temperature approaches the flashing point the rise of temperature, which for some time previously has been very uniform, becomes somewhat slower. The comparatively rapid heating at the commencement of the operation is decidedly advantageous, and the diminution toward the close is not sufficiently great to increase the legitimate severity of the test.

The temperature of 130° Fahrenheit has been fixed upon as a convenient one for the water to have at the commencement of the experiment; this temperature gives, with the apparatus of the dimensions adopted, a *mean* rate of heating of about 2° per minute during an experiment. The only operation which is to be performed in preparing for the heating of the petroleum to be tested is, at starting, to fill the heating vessel entirely with water at 130° Fahrenheit. The supply of water of the required temperature may be prepared by adding hot to cold water, or the reverse, in a jug, and watching the thermometer, which is moved about in the water until the desired temperature is indicated. When the heating vessel is filled with the properly warmed water, the petroleum cup being immediately afterward placed in position, the operator has not to concern himself any further with regard to the heating, and has only to attend to the rise of temperature in the cup and to the test flame. When the next test has to be performed, the water in the bath may be again raised to the proper temperature by the application of a spirit-lamp flame, and this is readily accomplished while the test vessel is being emptied and refilled with a fresh sample of the petroleum to be tested.

That the rate of heating must be rendered uniform by this mode of operation when the temperature of different samples of petroleum to be tested does not differ greatly is self-evident, and experiment has shown that, even if considerable differences exist between the temperatures of different specimens, the extra time required to raise the colder oil to the temperature approaching that of the minimum flashing point does not seriously affect the uniformity of the rate of heating at that part of the operation when this uniformity is of importance. There is, however, no difficulty whatever in avoiding any great variations in the temperatures of the samples tested at different times; thus, the warmth of the hand will soon raise a cold oil to a normal temperature, and a warm oil is easily cooled down to such a temperature by immersing the bottle containing it in water. As long as the temperature of the samples at the time of testing ranges between 55° and 65° the uniformity in their rate of heating will not be affected to an extent to influence the results furnished by the test. As illustrating the uniformity in the rate of heating, it may be stated that in two experiments made with one and the same oil, the temperature of which at the time of starting the test was 64° in one experiment and 70.5° in another, the average rate of heating during the rise of temperature from 75° to 85° was almost identical, being, during that portion of the test, 1.04° per minute. The only difference in regard to the heating in the two experiments was that with the oil at the lower temperature a period of six minutes was required to raise the temperature to 75°, while with the warmer oil only four minutes were required to attain the same result. The illustrations of results furnished by the proposed test apparatus given at page 224 show conclusively that they are not affected by differences even greater than the above in the temperatures of the oils at the commencement of the test.

The nature of the test flame to be used, and the mode of using it, were next considered by me, and very much time and labor have been expended upon the endeavor to provide a test flame which, with little care, could be maintained for some time of uniform size, and which might be allowed to remain throughout the testing operation or during the greater part of the time in a fixed position over the vapor chamber of the petroleum cup, my desire being, if possible, to render the actual operation of testing perfectly automatic.

Having satisfied myself that with the petroleum cup filled to a definite height there is no objection to keeping a small aperture in the lid of the cup (similar to that which exists in the lid of the close-test apparatus) constantly open, a very small oil-lamp was contrived, capable of maintaining a flame of the size of the test flames (furnished by a small gas jet or by twine) used in connection with the present test, and the lamp was so attached to the apparatus that when the testing was proceeded with the position occupied by the test flame over the opening in the cup was inevitably the same in all instances.

The variations in the length of time for which the flame was applied, in the rapidity of its movement in and out of the opening and in the frequency of its application, all constituted sources of discrepancy between the results obtained by different operators with the two tests hitherto used, which I proposed to set aside in the manner above indicated, *i. e.*, by keeping the small lamp in a fixed position from the time when the rise of temperature indicated an approach to the lowest attainable flashing point until the completion of the operation. This result was attained after numerous modifications of the small test lamp, and the form of the latter which I eventually adopted permitted of the attainment of uniformity in the size of the test flame by a very simple trimming operation.

The position in which the thermometer was fixed into the lid of the petroleum cup was modified so as to allow of the reading of the temperature simultaneously with the watching of the test flame being much more conveniently performed than in the present apparatus.

Although very satisfactory results were obtained by the arrangements just referred to, some difficulties were experienced in keeping the flame of the test lamp of uniform size throughout a consecutive series of test operations, and slight currents of air were found to affect the results obtained too greatly to render the test thoroughly reliable. After a long series of experiments, carried out with the view of overcoming these difficulties, I was eventually led to return to a method of operation very similar to that adopted in the original "close test", but with this important difference, that uniformity was secured in the nature of the test flame, the mode of applying it, and the position in which it is applied.

The application of the flame is in fact rendered quite automatic in the proposed form of test apparatus, the mode of operation being as follows:

The top of the petroleum cup has an aperture, as in the case of the old close-test apparatus, but in the center of the lid; this aperture is kept closed by means of a metal slide, working in grooves, and having two small uprights. These uprights support the little test lamp, which for this purpose is fitted at the upper part with small trunnions. When the temperature of the petroleum approaches that of the minimum flashing point, the slide is slowly drawn out of the grooves to the full extent permitted by a check; when this point is just reached, a very simple contrivance causes the test lamp to be tilted, so that the flame is always lowered into the opening in exactly the same position. Two seconds of time are allowed for withdrawing the slide, and thus the test flame is applied in all instances for the same period. (*a*) This operation is repeated at the termination of every degree indicated by the thermometer until the flashing point is attained.

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a A small weight, suspended in front of the operator from a string 2 feet in length, answers the purpose of regulating the opening and shutting of the aperture. The slide is gradually drawn open during three oscillations of the pendulum, and is then rapidly closed during the fourth.

In this, as in the old close-test apparatus, each time the aperture is reopened and the test flame is applied a small portion of the mixture of air and petroleum vapor necessarily escapes from the chamber, in consequence of the outward current established, and hence the proportion of air in the mixture of vapor and air formed in the chamber must become reduced each time the test is applied, and thus the ready explosiveness of the mixture is liable to some variation. A simple contrivance has been applied in conjunction with what may be called the "testing slide" for remedying this possible source of discrepancy in the test. The opening which the withdrawal of the slide exposes for the application of the test flame is in the center of the upper surface of the chamber. Just before it becomes open to the full extent, and the test flame is lowered into place, two smaller openings, one on either side of it, become also uncovered by the drawing back of the slide and serve to admit air to replace that part of the mixture of air and vapor which is withdrawn from the chamber by the current which sets in the direction of the test flame; as the slide is pushed back again, these two openings are closed the instant before the central opening is closed again.

The description of oil and wick most suitable for the little test lamp are given in Appendix II. When coal-gas is available, it may be substituted for oil in the production of the test flame, as being decidedly more convenient, and for this purpose an arrangement which can be used in place of the lamp, and which admits of a small gas frame being applied automatically in exactly the same manner as the oil flame, has been devised as an alternative adjunct to the apparatus.

Even with a strict adherence to the prescribed method of heating the petroleum to be tested, and with the employment of the automatic test arrangement constructed precisely in accordance with the instructions laid down in the appendix, uniform results would not be obtained in the application of the test unless the petroleum cup be filled in all instances up to to the same height, and, indeed, up to a height which a long series of experiments (varied in many ways) has demonstrated to be the one which best insures the attainment of uniform results. A simple gauge, consisting of a small bracket, terminating in a point, is fixed within the cup, and indicates the precise height up to which this is to be filled with the liquid, which has simply to be poured in gradually until its level just reaches the point of the gauge.

The thermometer which serves to indicate the flashing point is rigidly fixed into the lid of the petroleum cup in a sloping position, so that it enters the liquid at the center of the surface. The length of that part of the thermometer which is inclosed in the cup is so adjusted that when the latter is filled to the prescribed height the surface of the liquid is 0.2 inch above the bulb. The precautions combine to render the readings obtained with the thermometer reliable indications of the actual temperature of the petroleum during the testing operation. The sloping position of the thermometer scale enables readings to be very conveniently taken.

Detailed instructions with regard to the application of the proposed method for testing are given in Appendix II, and Appendix IV gives the details of the proposed test apparatus.

The method of testing, arranged as described, is so simple in its nature that any person of ordinary intelligence, after carefully reading the instructions, or after having been once shown the operation, can carry it out readily, and no experience is required for the attainment of uniform results with it.

The following results, not selected, which have been obtained with the pattern apparatus sent with this report, illustrate the uniformity in the working of the test as now elaborated, and it should be particularly noted with respect to these results that in experiments with one and the same sample considerable variations in the temperature of the oil at the commencement of the experiment did not affect the accuracy of the results obtained:

Sample.	No. of experiment.	Temperature of bath at commencement.	Temperature of oil when placed in bath.	Temperature at which testing was commenced.	Flashing point.	Sample.	No. of experiment.	Temperature of bath at commencement.	Temperature of oil when placed in bath.	Temperature at which testing was commenced.	Flashing point.
		Deg. F.	*Deg. F.*	*Deg. F.*	*Deg. F.*			*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
A.	1	130	66.0	68	77	K.	2	130	63.0	71	82
	2	130	68.5	70	77		3	130	66.0	69	82
	3	130	69.5	71	77	L.	1	130	54.0	68	75
B.	1	130	70.6	71	80		2	130	53.5	64	75
	2	130	71.0	71	80	M.	1	130	54.0	66	81
C.	1	130	68.0	70	82		2	130	67.0	69	81
	2	130	69.0	70	82	N.	1	130	57.0	63	73
	3	130	70.5	71	81		2	130	59.0	60	72
D.	1	130	59.0	63	75		3	130	57.0	63	73
	2	130	63.5	67	76	O.	1	130	62.0	67	79
	3	130	70.0	71	76		2	130	57.0	63	79
E.	1	130	57.0	65	72	P.	1	130	60.0	65	79
	2	130	59.0	62	71	Q.	1	130	59.0	65	74
	3	130	61.0	62	72		2	130	57.0	67	75
	4	130	68.5	69	72		3	130	67.0	67	75
F.	1	130	63.0	65	78	R.	1	130	66.0	69	78
	2	130	65.0	70	78		2	130	64.0	67	78
	3	130	66.0	67	78	S.	1	130	64.0	65	70
G.	1	130	70.0	70	84		2	130	63.0	64	70
	2	130	74.8	75	84	T.	1	130	63.0	66	80
H.	1	130	74.0	75	80		2	130	64.0	75	79
	2	130	65.0	66	80		3	130	65.5	75	80
I.	1	130	68.0	68	78	U.	1	130	66.0	67	73
	2	130	65.0	67	78		2	130	64.0	69	74
J.	1	130	59.0	68	79		3	130	67.0	68	74
	2	130	58.0	69	79	V.	1	130	67.0	69	80
K.	1	130	57.0	61	81		2	130	70.0	70	80

It will be seen that the foregoing table embraces a considerable range of flashing points; the samples which gave the results there recorded had flashing points ranging from 98° to 126°, as determined by the present legal test. All these were examined with equal facility and with equal accuracy (as shown by the results obtained with one and the same sample). the temperature of the water in the heating vessel having been in all instances 130° at starting. But with oils of much higher flashing points than the highest in the above

series the supply of heat furnished by the amount of water contained in the heating vessel, raised to a temperature of 130°, would not be sufficient; and even if in such cases the water in the bath be raised to a much higher temperature, the intervention of the air space between the petroleum cup and the source of heat (which plays an important part in regulating the source of heat in the ordinary use of the test) prevents the very high flashing oil from being raised to its flashing point within any reasonable period. If, therefore, the first experiment made in the ordinary prescribed manner with a sample of oil indicates a very high flashing point (about 100° or upward), the following modified mode of proceeding must be adopted for determining its flashing point. The air chamber which surrounds the cup is filled with cold water to a depth of $1\frac{1}{2}$ inches, and the heating vessel or water-bath is filled as usual, but also with cold water. The lamp is then placed under the apparatus and kept there during the entire operation. (*a*)

With this simple modification of the ordinary mode of working concordant results will be obtained with oils of the highest flashing points. It need hardly be stated that the greater majority of petroleum oils have flashing points within a smaller range than that represented by the annexed tabulated results, and that the application of the mode of proceeding last described will be limited to comparatively heavy paraffine oils, of which it is desired to determine the flashing points.

Having satisfied myself of the satisfactory working of the proposed test apparatus, I invited Mr. Keates, the consulting chemist to the Metropolitan Board of Works, and Mr. B. Redwood, the secretary of the Petroleum Association, to inspect it, and to witness the operation of testing with it. The appended extracts of letters (Appendix III) from those gentlemen show that they concur in considering that the difficulties which existed in connection with the present legal test, and also, though to a less extent, with the close test in the form in which it was proposed by Mr. Keates, are removed by the mode of operating which has been elaborated.

At the instance of Mr. Peter McLagan, M. P., the apparatus was also inspected by a representative of the Scottish Mineral Oil Association, Mr. John Calderwood, whose unqualified approval of it is recorded in the appended extract of a letter from him (Appendix III).

III.

With reference to the "flashing point", which, with the proposed test, should be fixed as equivalent to that of 100° Fahrenheit obtained with the present legal (open) test, and to the question whether the flashing point of 100°, or its equivalent, is "calculated to afford efficient protection to the public without unduly interfering with or restricting the trade".

With the view to establish the relation existing between the results furnished by the proposed test and by the present legal test experiments were made with a series of samples of petroleum, the flashing points of which had been determined by the test as prescribed in the act. Among these samples there was a considerable number for which I am indebted to the kindness of the secretary of the Petroleum Association.

As Mr. Boverton Redwood has had great experience in the testing of petroleum, both by the open test and by the close test, which it was at one time proposed to adopt, I requested him to attend at my office and test a number of the samples with which he was so good as to provide me.

In the first instance, however, I convinced myself that the results which that gentleman obtained by operating according to the directions laid down in the act, and also by applying the original close test, agreed very well with those obtained by Mr. T. W. Keates and by an experienced assistant in my establishment. Mr. Redwood and Mr. Keates were so good as to attend at my department to exhibit to me their ordinary mode of operating in applying the test, and the flashing points ascribed by those gentlemen (operating on different days) to particular samples were sufficiently in accordance to warrant my accepting the numbers obtained by Mr. Redwood in testing the series of samples referred to as representing the flashing points which would generally be obtained by experienced persons operating according to the methods hitherto practiced.

There is no doubt that the flashing points which one and the same operator, of such experience as Mr. Keates and Mr. Redwood, obtains with different samples of oil, using one and the same open test or close test apparatus, bear very generally a correct relation to each other; occasions will, however, unavoidably arise, even under the above very favorable conditions, when the defects inherent in those methods of testing will give rise to irregular and discordant results. Hence it is not to be expected that flashing points furnished by the comparatively accurate method of testing now proposed should present anything approaching absolute uniformity of relation to all those furnished by either of the other tests. Thus, as might have been anticipated, among the samples of oil which have been tested with the new apparatus there are several which, though they gave flashing points identical or nearly so with each other when examined by the present legal test (the open test), were found to differ several degrees from each other as regards their flashing points when examined by means of the new test.

In the examination of a number of samples by the new test and by the proposed close test the relation between the flashing points furnished by the two tests varied somewhat; the "new test" flashing points ranging from two to five degrees lower than the results furnished by the close test. Of 26 samples, ten gave flashing points with the new test 4° lower than the results obtained with the old close test, six gave results 5° lower, five 3° lower, and five 2° lower.

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a With oils of very high flashing points the rate of heating does not affect the accuracy of the results obtained. Therefore, if it is known to the operator that he is dealing with oils of very low volatility, he may save time by starting with the water raised to a temperature of about 120°. The following results are given in illustration of this:

Description of samples.	No. of experiment.	Temperature of bath at commencement.	Temperature of oil when placed in bath.	Flashing point.
		Deg. F.	*Deg. F.*	*Deg. F.*
I.				
Young's patent lubricating oil	1	78	78.0	147
	2	110	74.0	146
	3	120	80.0	147
II.				
Young's patent lubricating oil	1	74	74.0	131
	2	100	68.0	130
	3	100	72.5	131
	4	111	72.0	131

In applying the new test to 29 samples which had been examined by the present legal (open) test the following results were obtained:

Number of sample.	Flashing points by open test.	Flashing points by new test.	Difference.
	Deg. F.	*Deg. F.*	*Deg. F.*
1	98	70	28
2	100	71	29
3	100	72	28
4	100	74	26
5	100	75	25
6	101	73	28
7	101	78	23
8	101	74	27
9	102	75	27
10	103	75	28
11	104	75	29
12	104	76	28
13	104	77	27
14	104	78	26
15	104	78	26
16	105	80	25
17	106	79	27
18	106	80	26
19	106	81	25
20	108	82	26
21	108	83	25
22	108	80	28
23	109	84	25
24	110	83	27
25	110	82	28
26	110	81	29
27	110	81	29
28	113	87	26
29	126	100	26

It will be seen from an examination of these numbers that one among the samples gave a flashing point with the new test only 23° lower than that given by it when examined by the open test, while with four others there was as great a difference as 29° between the flashing points furnished by the new test and the present legal test. Excluding the single sample which showed the comparatively small difference above specified between the two tests the following is a synopsis of the observed differences between the two tests:

Number of samples.	Differences between the flashing points furnished by the two tests.
	Deg. F.
5	25
7	26
5	27
7	28
4	29

It would appear, therefore, from the results of these experiments, that the difference between the flashing points furnished by the present legal test and those obtained with the proposed new test ranges from 25° to 29° inclusive, and it should be borne in mind that the "new test" flashing points which have indicated this range of differences are all the results of two or three concordant experiments.

Taking samples of oil which by the "open test" gave flashing points of 100° and 101° (of which there are seven in the above series), the flashing points of these samples, determined by the "new test", ranged from 71° to 78° inclusive. Again, the flashing points of five samples, which were all shown to be 104° by the open test, ranged with the new test from 75° to 78° inclusive. Three samples, having all a flashing point of 106°, as determined by the open test, gave flashing points ranging from 80° to 82° inclusive by the new test; three, all flashing at 108° (open test), ranged from 80° to 83°, and four, flashing at 110° (open test), ranged from 81° to 83° inclusive. Oils of flashing points between 98° and 106° inclusive (open test) gave flashing points ranging between 70° and 80° by the new test, and those which with the open test ranged from 106° to 110° inclusive gave results with the new test ranging from 80° to 84° inclusive.

While the open test (the present legal test), and even the close test which has been proposed as its substitute, give what may be termed broad results, the new test, which appears to be as nearly absolute as a test of this kind can be made, gives precise results. For this reason, I am of opinion, so far as the results which have hitherto been obtained with the new test warrant my speaking decisively on the subject, that it will be necessary with the new test to adopt a range of 4 or 5 degrees to correspond to what has hitherto been regarded as the minimum flashing point which petroleum oils supplied to the public should have; in other words, I consider that the difference between the results furnished by the new test and the present legal test cannot be expressed by one figure, but must be represented by a range of figures (say, from 25° to 29°).

It need hardly be pointed out that great difficulties have arisen in connection with the present regulations respecting the testing of petroleum oils, consequent upon the legalized acceptance of oils as safe, or their condemnation as dangerous, upon a difference of even one degree in their flashing points, as determined by a test which may give differences of several degrees with one and the same oil in the hands of different operators.

With the adoption of a comparatively precise test, such as there is good reason for believing the proposed one to be, these difficulties should cease to exist, and I consider that a minimum flashing point may be adopted and strictly enforced with the employment of the new test without creating an opening for justifiable differences of opinion, such as have arisen in connection with the present legal test.

Having given my earnest attention to the evidence brought before the House of Lords committee in 1872, and to the questions which have arisen from time to time respecting the occurrence and causes of explosions or other accidents with petroleum, I have come to the following conclusions:

(1.) The present legal "flashing point" of 100° Fahrenheit by no means limits the acceptance of oils of that supposed flashing point to such as have only one particular degree of volatility, but indeed may admit oils as being just within the prescribed limits which really differ decidedly from each other as regards volatility.

(2.) There appear, on the other hand, to be no well-established grounds for considering that "adequate protection to the public" has not been afforded by adopting the flashing point of 100° Fahrenheit as the limit with the present legal test, or that the general results which that test has furnished in its application to determine whether oils imported have flashing points below the prescribed limit have been productive of risk to the safety of the public, even though there may be reason to believe that occasionally oils submitted as just within the limit have had decidedly lower flashing points than those of other oils which have been recorded as identical with them in this respect.

It may therefore be considered that the minimum flashing point to be adopted in connection with the new test may, without danger to the public, be fixed at that point which corresponds to the lowest results (not exceptional) which are furnished by applying the new test to a series of oils having a common flashing point of 100° when examined by the present legal test.

It may also be considered that the fairest course would be to base the equivalent, with the new test for 100° (furnished by the open test), upon the mean of the differences between the two tests applied to a large number of oils (with possibly the exclusion of a completely exceptionally extreme result). The objection would probably be raised against this course by importers of petroleum oils that it would have the effect of excluding from the market some oils which, under the present act, might be admitted as having a flashing point of 100°, and which past experience has failed to prove dangerous. Thus, if the mean difference between the flashing points given by the two tests in the results shown in the foregoing table be accepted as determining the equivalent for the present legal minimum flashing point (100°), then that difference being 27°, the equivalent for 100° would, with the new test, be 73°; but if that be adopted as the minimum legal flashing point with the new test, two out of 28 samples which the present legal test might have admitted would have been excluded from the market if the new test were in force.

Looking to the fact that these two particular samples, though found to have a flashing point of 100°, gave lower results than others of the same flashing point, not only with the new test, but also with the close test, it does appear as if they were oils of just that class which has given rise to occasional disputes, namely, oils which in the hands of some operators would have had flashing points below 100° assigned to them, and which might, therefore, even under the present conditions of testing petroleum, be excluded from the market by the balance of conflicting opinions.

After carefully considering this question, I have come to the conclusion that 27° Fahrenheit might, without injustice to the trade, be accepted as the difference between the results to be furnished by the new test and the present legal test; or, in other words, that 73° might with the new test be accepted as the equivalent for the present legal minimum flashing point of 100°.

It appears to me, however, that it would be much more satisfactory if, before a final decision is arrived at on this point, a very considerably larger number of experimental data than those which I have been enabled to obtain with the means at my command were procured with the new apparatus and by several operators experienced in the employment of the old tests. It would unquestionably much facilitate and expedite further action in the matter of modification of the existing law with reference to the testing of petroleum, etc., if Mr. Keates, of the Metropolitan Board of Works, Mr. Redwood, of the Petroleum Association, and an experienced operator selected by the Scottish Mineral Oil Association were invited to obtain test apparatus made in exact accordance with the pattern apparatus now submitted and to apply it to the testing of a number of samples of petroleum, the flashing points of which had also been determined by the present legal test. If portions of those samples, with the results obtained, were then forwarded to me by those gentlemen, apparent discrepancies could be examined into, and the "equivalent flashing point" of the new test be established upon a large number of results to the satisfaction of all interested in the adoption of a uniform system of testing.

If this suggestion be acted upon, I would recommend that the same person who, under my direction, has constructed the pattern apparatus, should make the apparatus required by those gentlemen, and that those apparatus should, in the first instance, be compared by me with the pattern now submitted.

In the event of the adoption of the new test, the apparatus submitted with this report (and of which photographs, (*a*) measurements, and specification are appended) should be preserved as a standard apparatus and placed in charge of some competent and suitable authority (*e. g.*, under the weights and measures office), who should inspect and test, or have tested, all apparatus which are made for use under act of parliament, for the purpose of ascertaining that they are in accordance with the pattern and specificaton. Such apparatus should then bear some official stamp or mark by which they can be identified as legal apparatus.

Since the attainment of uniform results with the test is dependent upon the uniform construction of the apparatus, it is indispensable that such a course should be pursued, and its adoption could, I apprehend, present no practical difficulties.

In conclusion, I submit, with special reference to the letter of the Secretary of State for the Home Department of July 7, 1875, 1386a 61, Appendix V, the following brief summary of the results and conclusions to which I have been led by the inquiry which forms the subject of this report:

(1.) The method of testing petroleum as prescribed in Schedule 1 of the Petroleum Act, 1871 (34 and 35 Vict., c. 105), is not "of a nature uniformly to insure reliable and satisfactory results".

(2.) A method of testing petroleum has been elaborated for adoption in place of that prescribed in the petroleum act, 1871, due regard having been had to the fact "that the testing must in many instances be carried out by persons who have had comparatively little experience in conducting delicate experiments". This method, while resembling in its general nature the one hitherto used, is free from the defects inherent in the latter, and is so arranged that it can be carried out, with the certainty of furnishing uniform and precise results, by persons possessing no special knowledge or skill in manipulation. With ordinary attention, in the first instance, to simple instructions, different operators cannot fail to obtain concordant results with it, and it is so nearly automatic in its nature that it is not, like the present method of testing, susceptible of manipulation so as to furnish different results at the will of the operator.

(3.) There are not, in my judgment, any well-established grounds for considering that the present flashing point of 100° Fahrenheit is not "calculated to afford adequate protection to the public".

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a These are necessarily omitted from this reprint.—B. R.

(4.) With the employment of the new test, a minimum flashing point should therefore be adopted which is equivalent, or as nearly as possible so, to the flashing point of 100° Fahrenheit, as furnished by the present test.

(5.) From the uncertain character of the present test, it follows that the "flashing points" furnished by it are not always concordant with oils of the same degree of volatility, and that the same flashing point is sometimes assigned by it to oils of different degrees of volatility. On the other hand, the comparatively very precise test now proposed furnishes, of necessity, concordant results with oils of the same degree of volatility. Hence the differences between the "flashing points" furnished by the present test and those obtained with the new test cannot be strictly represented by one figure, but may be considered as ranging from 25° to 29° Fahrenheit (inclusive).

(6.) The results of a number of thoroughly concordant experiments with the new test, and a comparison of these results with those furnished by the present legal test, and also with those obtained by employment of the close test, which it was proposed to adopt in 1872, indicate that a mean difference of 27° Fahrenheit may be legitimately accepted as the mean difference between the present test and new test, and that therefore a flashing point of 73°, furnished by the new test, may be accepted as equivalent to the minimum flashing point of 100° adopted in connection with the present test.

(7.) Although the conclusions given in the preceding paragraph are based upon the results of a number of carefully conducted and controlled experiments, it appears desirable that the minimum flashing point to be adopted in connection with the new test should be deduced from the results of a much larger number of experiments, and that these should be carried out with the proposed test apparatus by several independent operators of acknowledged experience in the testing of petroleum according to the methods hitherto practiced.

(8.) It is therefore proposed that several test apparatus, precisely similar in construction to that submitted with this report, be prepared, and that, after having been found by me to furnish identical results, they should be employed by the chemist of the Metropolitan Board of Works, the secretary of the Petroleum Association, and a duly qualified representative of the Scottish Mineral Oil Association for the testing of a number of samples of petroleum, the results, together with portions of the samples tested, being forwarded to me, with the view of their forming a basis for final report to the Secretary of State for the Home Department on that particular point.

(9.) In the event of the adoption of the test apparatus submitted with this report, it is important that the standard apparatus, with drawing and specification, should be deposited with some government authority, whose duty it would be to examine and certify to the correctness of all apparatus made for the purpose of testing petroleum under the new legalized regulations.

F. A. ABEL,

AUGUST 12, 1876. *Chemist of the War Department.*

Immediately upon receiving this report from Professor Abel, the Secretary of State for the Home Department requested Mr. Boverton Redwood to subject a large number of samples of oil to comparative tests, in order that the relation between the temperatures at which oils flashed when tested under the act of 1871 and when tested by the apparatus contrived by Professor Abel might be accurately determined.

The samples tested numbered 1,000. They represented (excluding the trial samples) 97,766 barrels of oil, and formed a series thoroughly indicating the character of the various shipments which have reached England from the United States during a period of six months. The following is a synopsis of the results, taking the first 968 samples, all of which consisted of the ordinary (refined) petroleum of commerce:

92 samples showed a difference between the two tests of	25°
208 samples showed a difference between the two tests of	26°
225 samples showed a difference between the two tests of	27°
281 samples showed a difference between the two tests of	28°
162 samples showed a difference between the two tests of	29°
968	

Therefore, the whole of these samples afforded results within the range of figures given in Professor Abel's report.

On the other hand, it will be noted that the majority of the last 32 samples gave differences smaller than the minimum figures of Professor Abel's results, the difference being as follows:

9 samples showed a difference between the two tests of	20°
1 sample showed a difference between the two tests of	21°
9 samples showed a difference between the two tests of	22°
1 sample showed a difference between the two tests of	23°
4 samples showed a difference between the two tests of	24°
8 samples showed a difference between the two tests of	25°
32	

These, however, all consisted not of ordinary petroleum oil, but of the special kind which is known in the trade under the name of "water-white" oil, and therefore the exceptional results afforded by them do not affect the question at issue, and are of interest only as showing that samples may be selected or specially prepared having flashing points by the two systems more closely approximating than those of the ordinary petroleum oil of commerce. This water-white oil, as is well understood, possesses the distinctive feature of low specific gravity in addition to that of high flashing point, being, in fact, produced at a considerably enhanced cost, by rejecting, in the process of distilling the crude oil, an unusually large proportion of the heavier as well as of the lighter hydrocarbons; and it is possible that this peculiarity may account for the smaller difference between the two tests, though I can suggest no explanation of its occurrence only with *some* parcels of water-white oil, unless it be that the special mode of manufacture referred to is more carefully carried out in some cases than in others. (*a*)

On the whole, the results which I have obtained afford a complete corroboration of those given in Professor Abel's report. The selection of a mean difference of 27°, or, in other words, of a standard of 73° with the new test, would undoubtedly, as is evidenced by my figures, lead to the condemnation by the committee of the Petroleum Association of a somewhat larger percentage of the oil imported, and would thus place the trade in a more unfavorable position; but, on the other hand, the adoption of a precise method of testing would reduce to a minimum those differences of opinion which, under the present system, may, as Professor Abel points out, lead in certain cases to the legal condemnation of oils which the trade inspection has shown not to come within the provisions of the petroleum act. (*b*)

a These "water-white" oils were not cracked oils.—S. F. P.

b Report of Mr. Boverton Redwood to the English Secretary of State for the Home Department.

It is not my intention in this report to advocate the claims of either the Saybolt, the Abel, or the Engler apparatus for testing oils, which are doubtless superior to all the others, but simply to present the subject as it actually exists, with all the difficulties attending it, and also such attempts as have been made to meet them.

SECTION 4.—PETROLEUM LEGISLATION IN THE UNITED STATES.

In order to secure full information regarding legislation regulating the sale of petroleum products a schedule of questions was prepared and sent to the executive officer of each of the cities and towns having a population of 10,000 and upward, as represented in Census Bulletin No. 45. Some of these schedules were filled with very great care, others were carelessly filled, others were returned with an indorsement of "no legislation" or something equivalent, and in some cases no return was made. The same schedule was also addressed to the secretaries of the different states and the secretaries of the different state boards of health, from nearly all of whom returns were received. I was present in April, 1881, at a meeting of the committee of the New York legislature having in charge the legislation then pending relating to the sale of petroleum products, and was also frequently consulted by committees of the Minnesota legislature during the successive years in which the subject was agitated in that state.

From these several sources of information, of both a negative and a positive character, it appears that at the close of the census year seventeen out of the thirty-eight states of the Union were without other legislation relating to petroleum than that provided by the United States statute of 1867 (*a*) regarding mixing oils and prescribing a test of 110° (not given in the Revised Statutes), and an act regarding dangerous freight or stores on passenger steamers, (*b*) except that within those states there was a large number of cities having ordinances providing some test. Even the District of Columbia, whose laws are directly prescribed by Congress, has no other petroleum laws than the United States laws indicated above. Since the close of the census year a number of these seventeen states have passed laws relating to petroleum.

It was found to be impossible to compile any general statistics as to laws even from the schedules that were most carefully filled; but the returns exhibited the confused condition of legislation regarding petroleum enacted by so many different legislative bodies more or less influenced by a great variety of opinions and interests. On the one hand there are advocates of extremely high test laws who have made their influence dominant in certain localities, and that influence has produced legislation that has either been openly disregarded or strenuously opposed until the repeal of the obnoxious laws had weakened the cause they were intended to strengthen. On the other hand, while there are honorable manufacturers of petroleum who make and sell safe oils and desire to be relieved from competition with the manufacturers of unsafe products, there are others who, without regard for the welfare of the public, desire to be allowed to make what they can sell, leaving the question of responsibility with the purchaser, and who therefore oppose all legislation, using their influence to secure the lowest test possible when legislation is inevitable.

When the United States law of 1867 was passed the proportion of cracked oils in the market was much smaller than at present. That law required a fire test of 110° F. I have been unable to ascertain upon what basis the adoption of this test and the temperature rested. Several years subsequent to the enactment of this law the board of health of the city of New York made the whole question of dangerous petroleum products the subject of a most elaborate research by Dr. C. F. Chandler, and in consequence rejected the "fire test" as worthless and recommended to the city government the enactment of an ordinance that required a "flash test" as the only one of any value. The wisdom of this action has been indorsed by the whole course of English petroleum legislation. Some of the most able scientific men of this generation, after careful investigation of the subject, have shown that

a And be it further enacted, That no person shall mix for sale naphtha and illuminating oils, or shall knowingly sell or keep for sale or offer for sale such mixtures, or shall sell or offer for sale oil made from petroleum for illuminating purposes inflammable at less temperature or fire test than one hundred and ten degrees Fahrenheit, and any person so doing shall be held to be guilty of a misdemeanor, and on conviction thereof, by indictment or presentment in any court of the United States having competent jurisdiction, shall be punished by a fine of not less than one hundred dollars, nor more than five hundred dollars, and by imprisonment of not less than six months nor more than three years. (U. S. Stat. at Large, Thirty-ninth Congress, second session, 1867, chap. 169, sec. 29.)

As this section is a part of an act relating to internal revenue, the other sections of which have no relation whatever to petroleum legislation, it is an open question if, in the repeated revisions to which the internal revenue laws have been subjected, section 29 has not been long ago repealed.—S. F. P.

b SEC. 4472. No loose hay, loose cotton, or loose hemp, camphene, nitro-glycerine, naphtha, benzine, benzole, coal-oil, crude or refined petroleum, or other like explosive burning fluids or like dangerous articles, shall be carried as freight or used as stores on any steamer carrying passengers. * * * Refined petroleum which will not ignite at a temperature less than one hundred and ten degrees of Fahrenheit thermometer may be carried on board such steamers upon routes where there is no other practical [practicable] mode of transporting it, and under such regulations as shall be prescribed by the board of supervising inspectors with the approval of the Secretary of the Treasury. * * *

SEC. 4474. The Secretary of the Treasury may grant permission to the owner of any steam vessel to use any invention or process for the utilization of petroleum or other mineral oils or substances in the production of motive power, and may make and enforce regulations concerning the application and use of the same for such purpose. * * *

Sec. 4475 prescribes the packing and marking of such oils, and Sec. 4476 prescribes the penalties for violation of the law. (Revised Statutes, U. S. Ed., 1878.)

a "fire test" is unsatisfactory, and also that a "flash test", at a temperature equivalent to that of 100° F. in an open tester, is a satisfactory test to insure public safety. Oils that will sustain a "fire test" of 110° often flash at 70° to 80°. While the overwhelming mass of evidence goes to show that a flash test of 100° is conclusive as regards public safety, there are large areas of the country with flash tests fluctuating between 120° and 150° as successive legislatures deal with the question, and other large areas where there is no state legislation. Under both these conditions the number of "kerosene accidents" is very large, while that portion of the country over which petroleum legislation is really effective is comparatively small.

The acts that have proved most effective in affording protection to the public have provided that a state inspector, authorized to appoint deputies, shall be chosen by the governor, county judges, or state board of health, who shall inspect oils by testing each for either its flashing or its burning point, or for both, at a specified temperature. Provision is usually made for the payment of the inspector and deputies. In some instances this compensation is made too low to compensate a competent person for doing the work properly. The instrument with which the test shall be made is in many cases carefully described. Then the bonds of the inspector and of the deputies are fixed, and the penalties for violation of the provisions of the law are prescribed.

There are two sources of danger against which legislation should be directed. The first is the *manufacture* of unsafe oils; the second is the preparation of unsafe oils by *mixture*. The machinery of state inspection is cumbersome as related to the manufacturers, and inoperative as regards the dishonest, who will mix safe oils with benzine. The expense of an analysis or inspection of every barrel of oil sold in this country in such a manner as to be of any value is unnecessary, as these oils are transported in tank cars that hold on an average 100 barrels. The inspection of the contents of a car is of just as much value as the inspection of each particular barrel. The idea that one part or stratum of a tank of oil will test differently from another has no foundation in fact. Having conversed with a large number of persons connected with the petroleum trade, I am convinced that legislation embodying the following provisions would reduce the number of petroleum accidents to a minimum, and would meet the approval of all honorable men. To determine, as a first step, what method of testing, what instrument, and what temperature should be adopted as a standard of legislation, the President might be authorized by Congress to appoint a commission, in which the boards of health, scientific experts, and manufacturers of petroleum should be represented equally. It would be well to ask the governments of foreign countries, with which the trade in petroleum is large, to join in the consideration of this question through special commissioners. A small percentage of the losses of the country during a single year would pay all of the expenses of this commission. Upon the report of such a commission, laws could be based making the selling of a dangerous oil a misdemeanor in all cases, and manslaughter when death is occasioned by its use, as already provided when death results from illegal transportation of "nitric oils" and powder, and also providing for the recovery of damages in a civil suit for all losses to either persons or property occasioned by the use of such oil—the retailer to be able to recover from the jobber, the jobber from the manufacturer, etc., until the responsible party is reached. One competent person, who should be authorized to enter premises and demand samples of oil for inspection, could do all of the necessary work for a large state, and he should be paid an adequate salary, not paid by fees. The examination of oils should not be confined to the flashing point alone, but should regard the percentage of sulphur, of benzine, and of heavy oil as well. This suggestion has met the approval of persons representing the producing, the manufacturing, and the selling interests as one which would make the manufacture of unsafe oils unprofitable, and, in addition, would prescribe penalties for the man who would willfully mix benzine with a good oil, tending to stamp out that nefarious business. In addition to a standard of testing for ordinary illuminating oils, another and much higher standard should be determined for oils to be used on steamboats and railroad cars in interstate commerce. Under present legislation, a car running over a thousand miles of road may start in a state in which a 110° oil is legal, and, passing through another in which a 300° oil is required, finish the run in a third state in which there has been no state legislation. As a further illustration of the results of such variable legislation, I may state that while engaged in collecting the statistics for this report I saw in the testing room of a large refinery a large table, on which were no less than seven different instruments that were in daily use for testing oils to fill orders from different localities. These instruments included Abel's for the Canada market, Saybolt's for the New York city export market, the Ohio tester for the Ohio market, and a number of others. I doubt if the legislative regulation of any other substance presents such anomalous and contradictory characteristics.

There is but one temperature at which illuminating oils manufactured from petroleum can, when properly tested, give off an amount of vapor sufficient to produce an explosive mixture within the limits of public safety. That temperature alone should be made the subject of legislation, and the testing should be made with whatever instrument gives results that may be repeated with the greatest accuracy. The question of absolute safety has already been discussed; that of comparative economy is outside the domain of legislation.

SECTION 5.—BURNERS.

One other subject deserves consideration in this connection. It is frequently maintained that with proper burners oils are safe that under other conditions are unsafe. While it cannot be denied that some burners are to be preferred to others, it is my belief *that all burners are safe with safe oil.* There is no doubt, however, that very considerable differences obtain between different burners in point of illuminating power, and hence of economy. This was made a subject of research by Mr. C. J. H. Woodbury in 1873. (*a*) In his report he says:

The comparative worthlessness of the lighter product of petroleum tempts the unprincipled manufacturer to add them to kerosene, making a product which, on account of its extreme volatility, is *cleaner* than pure kerosene; the flame is of greater brilliancy, and, on these grounds, it recommends itself over the pure oil to those who have not been able to give attention to this subject. Many of these compounds are quite as dangerous as gunpowder. As kerosene has been in use only a few years, a sufficient interval has not elapsed to enable us to burn it with the greatest possible economy. * * * The writer, in the following series of experiments upon various kerosene burners, has endeavored to ascertain the most favorable forms of burner for an economical expenditure of oil compared to the light given. The results given for each lamp are the mean of from 150 to 250 observations.

FLAT WICKS.

No.	Chimney.	Wick.	Candle power.	Hours required to consume 1 gallon.	Candle power to gallon.
		Inch.			
1	Bulge	$\frac{5}{8}$	8.469	99.06	594
2	Bulge	$\frac{5}{8}$	6.426	127.53	815
3	Bulge	$\frac{5}{8}$	6.587	125.35	823
4	Sun	$\frac{5}{8}$	5.138	163.93	829
5	Sun	$\frac{5}{8}$	4.829	171.89	830
6	Sun	$\frac{1}{2}$	4.810	174.87	835
7	Bulge	$\frac{5}{8}$	7.398	115.23	887
8	Sun	$\frac{5}{8}$	7,371	131.19	964
9	Sun	$\frac{5}{8}$	5.997	188.57	1,110
10	Bulge	1	10.754	113.17	1,209
11	Bulge	$\frac{7}{8}$	*19.480	....	....
12	Bulge	$\frac{1}{2}$	*10.030	....	....

* As these lamps were made to burn mineral sperm oil, we do not give the results.

CIRCULAR WICKS.

No.	Chimney.	Wicks.	Candle power.	Hours required to consume 1 gallon.	Candle power to 1 gallon.
13	Circular	Circular..	8.387	101.20	833
14	Circular	Circular..	8.824	103.68	911
15	Circular	Circular..	10.905	123.68	1,347

The list could have been made much longer, but it would serve our purpose no better.

The oil used was Downer's kerosene, specific gravity 0.801. One gallon, at 62° F., weighing 3,025.3 grams. The first column of results shows the candle power given by the lamp when burning with a full flame, but below the smoking point. The second gives the number of hours required to consume 1 gallon of oil. The object of the third column is to give the economy of the lamp, by a unit, which is the candle power given by an ideal lamp, exactly similar to the one under observation, with the exception that it shall consume precisely 1 gallon an hour. This result is constant for all except extremely high or low flames. Such a unit is very empirical, but no more so than the modulus of elasticity, or absolute zero. * * *

A simple inspection of the above lamps shows their economical results to be in the direct ratio to the facilities afforded the air for approaching the base of the flame. Where the air cannot enter freely, much of the oil seems to be volatilized without combustion. The best example is given by cases 5, 8, 9, and 10. The lamps are all similar, except in the difference noted below, and are of the pattern generally known as "sun-burners". In the first example, the air must pass through two horizontal brass diaphragms at the base of the chimney; one is pierced with holes $\frac{3}{8}$ inch in diameter, the other about $\frac{1}{16}$ inch; case 8, one fine diaphragm at base of chimney; cases 9 and 10, the base of the chimney is open; a diaphragm is near the base of the flame. Although the two lamps are different in size, they are identical in principle, the following being the cause of difference in the result: a certain portion of the light is shaded by the top of the burner. This conceals an equal amount (not proportion) of the flame, whether it is high or low. Also, a large flame makes a much more powerful draft than a smaller one. If we have two similar lamps, the larger one will give the best results.

In the four lamps just cited, if we remove the coarse diaphragm from the first lamp we increase its efficiency 16 per cent.; in addition, taking away the fine one, we increase it 18 per cent. more; make the draft more powerful by a bulge chimney, we have a further increase of 12 per cent. Lamps like 9 and 10, from their open construction, are extremely sensitive to currents of air. Lamp No. 3 is a metallic lamp, and very thoroughly constructed. The air is supplied from the base of the lamp, the burner being closed; it is not sensitive to currents of air, and gives the most steady and agreeable flame of any that have come under observation. If the entrance to the air passage was made larger, and the diaphragms in the burner were pierced with larger holes, the efficiency of the burner would be increased greatly, while it would probably retain its steadiness of flame. In lamp No. 15 the air is introduced into the center of the flame with less obstruction than in the two previous cases, and this lamp gave the most economical results.

a Jour. Frank. Institute, xcvi, 115. The names of the burners and their manufacturers are given in the original memoir.

The results here given show that in the question of the economical combustion of illuminating mineral oils much depends upon the burner. At the special general meeting of the London Petroleum Association, held on January 14, 1879, it was generally admitted that not only the burner, but the wick, played an important part in the successful combustion of petroleum oils. It was also shown on that occasion that a loosely woven wick was preferable to a more solid one, but that with any form of wick or burner oils of inferior quality produced a crusted wick with a smoky flame and heated burner. Judging from the discussion that took place on that occasion, together with my own experience, I conclude that oils that are prepared from petroleum without destructive distillation may be burned with a very slow consumption of the wick, but that the wick used with these oils, in time, through some physical or chemical action which has not yet been investigated, suffers impaired capillarity and becomes unfit for use, although it may still be of sufficient length to reach the oil. Such wicks should be discarded as soon as they give trouble. Burners also should be discarded as soon as they become worn and do not act satisfactorily. The primary question, however, rests with the oil. Cracked oils containing much heavy oil and a comparatively large content of sulphur very soon convert a wick into a charred mass saturated with a gummy substance that partially destroys its capillarity and produces an imperfect combustion and inferior flame. To secure the best results the best oil should be burned in lamps supplied with fresh burners and wicks carefully trimmed.

The fact has been established beyond all controversy *that no combination of lamp, burner, and wick that has ever been invented or can be invented will make an inferior or unsafe oil either satisfactory, economical, or safe.*

Dr. Thomas Cattell writes as follows to an English journal:

It is two years since the first intimation of danger from sophisticated candle-wick was forced on my attention. The candle, a thick dipped one, was placed lighted upon a table, and after a period of about twenty minutes it guttered so violently that the tallow flowed down on to the table around the bottom of the candle-stick, followed in a few seconds by a collapse of the wick, bared of tallow, on to the table, setting fire to the melted tallow. If I had not been present serious consequences would have ensued. When this incident occurred I had not thought the fault lay primarily with the candle-wick; I held the tallow to blame. A recent accident, however, with a large paraffine lamp has brought to light the fact that the medium or wick through which the tallow and the oil are used as sources of light is unsuitable for its object, as well as fraught with considerable danger. Experience has taught that cotton is the one peculiar and valuable medium for supplying the sources of light here referred to. Spurious cotton-wick I believe to be a mixture of cotton and flax waste, or a combination of jute, hemp waste, and cotton. Such wick, or at least the alien portion of it, becomes quickly carbonized both in candles and lamps. With the first, the carbonized particles as they form dart out with a flash or drop on the melted tallow undergoing absorption by the wick, giving rise to guttering and a great waste of tallow. In the other, the ignited portion soon carbonizes, which more and more increases in depth, until a point is reached when further capillarity in the direction of the flame ceases and ignition of the lower part of the wick takes place, followed by that of the oil in the receiver, with explosion or other mishap. I believe it will be found that the danger to which I here allude will afford an explanation of many fires and accidents that, but for these observations, had ever remained involved in mystery. Pure cotton-wick is slow to carbonize, and its consumption is uniform, unaccompanied by sudden little ejections and explosions, as occur in the burning of spurious cotton-wicks previously alluded to. If ordinary paraffine oil be not of the required combustion standard, such wick would greatly increase its danger. Microscopically, flax fiber consists of jointed cylindrical tubes. Cotton consists of flattened twisted tubes without joints. Chemical analysis would give us more or less of the nitrates, nitrites, and binitrites of cellulose. (*a*)

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a Oil and Drug News, January 31, 1882.

CHAPTER III.—NATURAL GAS AND THE CARBURETING OF GAS AND AIR.

SECTION 1.—OCCURRENCE AND COMPOSITION OF NATURAL GAS.

The occurrence of springs of water accompanied with gas have been noted from a very early period. The number of localities named "burning springs" in different parts of the country attest the wide distribution of this phenomenon. It is, however, very erroneously supposed by some writers that these burning springs are immediately related to volcanoes. Dr. Ansted appears to think that they are closely related to mud volcanoes; but in the United States, east of the Mississippi river, where mud volcanoes are unknown, it appears that gas springs are the product of the same kind of action that has produced petroleum, and they often accompany petroleum. Wall observed in his researches upon Trinidad that—

The phenomena of salses or mud volcanoes, consisting of the solution of inflammable gas, accompanied by the discharge of a muddy fluid and asphaltic oil, is, perhaps, closely related to the activity just described, as carbureted hydrogen may be disengaged in the direct formation of asphalt.

Several of them occur in Trinidad, also in the "Newer Parian". They were likewise observed in the province of Maturin, presenting similar characters. At Turbaco, near Carthagena, precisely the same action is manifested, but on a much larger scale. This is further confirmatory of a great extension of the above formation to the westward. The thermal waters of Trincheras, near Valencia, issuing from mica-schist, contain merely traces of silica, sulphureted hydrogen, and nitrogen, and possess a variable temperature, as shown by the following determinations:

Humboldt, in 1800	194°
Boussingault, in 1823	206°
The author, in 1859	198°

T[illegible] hot springs of Chaquaranal, near Pilar, in a limestone of the "Older Parian", present the rare phenomena of water disch[illegible] at and even above the boiling point. Sometimes the fluid is delivered under pressure, rising in a jet, continuing in a state of ebul[illegible] for several feet from the point of discharge, accompanied by a forcible evolution of steam, and depositing abundance of calcar[illegible] matter.

Th[illegible] fissures of the adjacent rock are lined with spathose crystallizations and the acicular forms of sulphur. The vapors escaping from th[illegible] fissures consist principally of steam. (*a*)

Professor Ansted observed copious discharges of gas, petroleum, and mud from the mud volcanoes of the valley [illegible] Pescara, in Italy, and also in the Crimea. I do not, however, interpret these phenomena as volcanic, or as in [illegible] manner an association of cause and effect, but rather as associated incidents of the dying out of the meta[illegible] ic action which has in most cases by invasion of strata containing organic matter distilled all of the form[illegible] itumen, including inflammable gas. The observations of Wall confirm this hypothesis in the most striking man[illegible]

[illegible] great petroleum region of the Appalachian system the accumulations of gas are often found upon the ant[illegible] in the pebble conglomerates and sandstones that hold the petroleum, while at a still lower level in the trou[illegible] the synclinals salt water occurs. In a general manner, with the sea-level as a datum line, the Venango and [illegible] al oil-sands lie sloping at a gentle inclination, the southwestern edges submerged in salt water, and the nor[illegible] edge saturated with gas under an enormous pressure. Not the slightest evidence that volcanic action ev[illegible] ained in that region has been observed; but all the geological features, which have already been so ful[illegible] sed on previous pages of this report, lead to the conclusion that petroleum and natural gas have been pro[illegible] the same cause. That volcanic action is not that cause is further shown by a comparison of the analyses tha[illegible] en made of natural gases from various localities.

Professor S. P. Sadtler, of the University of Pennsylvania, examined with great care the gas from four dif[illegible] ls in northwestern Pennsylvania, which was used in all cases for technological purposes. I quote fro[illegible] r read before the American Philosophical Society, February 18, 1876, as follows:

[illegible] d occasion lately to analyze some of the gases issuing from wells in western Pennsylvania, I have obtained some results wh[illegible] as a contribution to our knowledge of these important natural products. There have been almost no analyses whatever ma[illegible] gases. In 1866 a French geologist, M. Foucou, visited a number of these gas-wells and collected specimens of the gases. Th[illegible] afterward analyzed by M. Fouqué, and the results published in *Comptes Rendus*, lxvii, p. 1045. The localities were Pioneer run, [illegible] ounty, Pennsylvania; Fredonia, New York; Roger's gulch, Wirt county, West Virginia; Burning Springs, on the Niagara river [illegible] the cataract; and Petrolia, Enniskillen district, Canada West. These points are certainly widely enough removed to make th[illegible] prehensive from a geological standpoint. The analyses do not appear to have been complete ones, as M. Fowqué determined th[illegible] amounts of only a few of the constituents. In general, the gases were composed of the marsh-gas series of hydrocarbons. Th[illegible] gas from Pioneer run he found to have essentially the composition of propyl hydride (C_3H_8), with small quantities of carbonic acid and of nitrogen; the Fredonia gas appeared to be a mixture of marsh-gas (CH_4), and ethyl hydride (C_2H_6), with a small quantity of carbonic acid and 1.55 per cent. of nitrogen; the Roger's gulch gas was CH_4 almost exclusively, with 15.86 per cent. of carbonic acid and a small quantity of nitrogen; the Burning Springs gas almost pure CH_4 with a little CO_2; the Petrolia gas a mixture of marsh-gas

a Q. J. G. S., xvi, 467.

(CH_4) and ethyl hydride (C_2H_6), with a small amount of carbonic acid. However, the composition as given was only apparent, as in the case of the Pioneer run gas, for on passing the gas through alcohol a part was absorbed, which was afterward shown to be butyl hydride (C_4H_{10}), while the part unabsorbed showed nearly the composition of marsh-gas (CH_4). It was evident, therefore, that what appeared to be propyl hydride (C_3H_8) was in reality a mixture of marsh-gas (CH_4) and butyl hydride (C_4H_{10}).

In 1870 Professor Henry Wurtz made an analysis of the gas from a well 500 feet deep in West Bloomfield, Ontario county, New York. He found:

	Per cent.
Marsh-gas CH_4	82.41
Carbonic acid CO_2	10.11
Nitrogen N	4.31
Oxygen O	0.23
Illuminating hydrocarbons	2.94
	100.00
The specific gravity of the gas was	0.693

Professor S. A. Lattimore, of Rochester University, New York, examined this gas in 1871, and estimated its flow to be 800,000 cubic feet in twenty-four hours of 14.42 candle power.

The gases which I collected and analyzed were: First, the gas of the Burns well, in Butler county; secondly, that of the Harvey well, in the same county; thirdly, that from the Leechburg well, across the Kiskeminitis river from Leechburg, in Westmoreland county; and fourthly, the gas bubbling from a spring at Cherry Tree, in Indiana county.

He obtained the following results: (*a*)

COMPOSITION OF THE GAS OF CERTAIN WELLS.

Name of well.	Carbonic acid.	Carbonic oxide.	Illuminating hydrocarbons (C_nH_{2n+2}).				Oxygen.	Nitrogen.	Specific gravity.	Heating power.	Pyrometric heating power.
			Hydrogen.	Marsh-gas.	Ethyl hydride.	Propyl hydride.					
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Deg.*
Burns' gas-well	0.34	Trace.	6.10	75.44	18.12	Trace.	......	......	0.6148	14,214	2,745
Leechburg gas-well	0.35	0.26	0.56	89.65	4.39	Trace.	......	......	0.5580	14,105	2,746
Harvey gas-well	0.66	Trace.	13.50	80.11	5.72	Trace.	......	......	0.5119	15,597	2,763
Cherry Tree gas-spring	2.28	......	22.50	60.27	6.80	......	0.83	7.32	......	......	......

The following results were obtained from the analysis of the gas escaping from a well in Belfast, Ireland. It passed through 33 feet of silt and 7 feet of gravel containing organic *débris.* The gas escaped from the gravel. Its density was 0.661, air = 1, inodorous, and contained no compounds of carbon and hydrogen, except CH_4. Its composition was found to be—

	Per cent.
CH_4	83.75
CO_2	2.44
O	1.06
N	*b* 12.75

An analysis is here given of the gas of the Burning Spring of Saint Barthélemy (Isère): (*c*)

	Per cent.
CH_4	98.81
CO_2	0.58
N	0.48
O	0.10
Loss	0.03
	100.00

The results of several analyses of the gases escaping from the solfataras and fumaroles, given below, will be found to exhibit a strikingly different composition. The first is an analysis of the gases rising through the Lago di Naftia in the Val del Bove of Etna:

	I. Per cent.	II. Per cent.
CO_2	94.23	84.58
H_2S	-----	6.17
CH_4	1.82	2.42
O	0.28	4.52
N	3.79	1.89

Neither acetylene nor olefines were present. (*d*) The next is an analysis of the gases evolved from fumaroles on the island of Saint Paul. The temperature was 78°–80°: (*e*)

	Per cent.
CO_{21}	14.24
O_1	17.01
N_1	68.75

a *American Chemist*, vii, 97; W. B., 1876, p. 1134.

b C. N., xxx, 136; J. C. Soc., xxviii, 242.

c *Mont. Sci.*, 1870, p. 550; W. B., 1870, p. 704.

d *Gaz. Chim. Ital.*, ix, 404; J. C. S., xxxviii, 345.

e *C. Rendus*, 1875, No. 7.

The gas from Campi Flegrei, Vesuvius, is not constant in composition, but is mainly CO. H_2S is about 5 per cent., O less than 1 per cent., N 5 to 10 per cent., sometimes as high as 50 to 60 per cent., with occasionally a small quantity of CH_4. The Grotto del Cane yields pure CO. (*a*) No combustible gases are evolved by the Caldeira de Fumas, San Miguel, Azores, differing in this respect from the geysers of Iceland and the Suffoni of Tuscany, both of which invariably contain H and CH_4. (*b*) The gases from Santorin, after the eruption of 1866, contained CO_2, O and N in constantly varying proportions, with traces of H, H_2S, and CH_4. In 1870 HCL and SO_2 were present. (*c*) The gases evolved from solfataras contain CO_2, H_2S, O, and N. Two of them yielded wholly CO_2. The Great Solfatara yields steam, H_2S, CO_2, O, and N. (*d*)

A comparison of these results of analysis shows the great difference between the constituents of the gases from these two sources. In the gases from Burning Springs CH_4 predominates, accompanied by other products of *distillation;* in the gases from solfataras CO_2 predominates, accompanied by other products of the *combustion* of carbon. The distillation of strata rich in organic remains, when invaded by metamorphic action, has doubtless produced the inflammable gases of burning springs and gas-wells in a manner analogous to and often simultaneous with the production of petroleum.

In the United States the phenomena of burning springs were observed by the earliest settlers west of the Alleghanies. Dr. Hildreth described these springs as they occur in the valleys of the Little and the Great Kanawha, in West Virginia, in 18[illegible]3, and later in the valley of the Big Sandy, in Kentucky. The volume of gas escaping from these springs is often remarkable, but no attempt was ever made, so far as I can learn, in any manner to utilize this material. The boring of wells for salt and petroleum led to the frequent penetration of strata heavily charged with gas that was destitute of petroleum. This was most frequently the case on the borders of petroleum fields in rocks that were, relative to the sea-level, higher than those yielding oil. The localities that have been and are most noted for their gas-wells are: Fredonia, Chautauqua county, New York; Wilcox, Elk county, Pennsylvania; Rochester, Beaver county, Pennsylvania; Burns well and Harvey well, Butler county, Pennsylvania; Leechburg, Westmoreland county, Pennsylvania; Sheffield, Warren county, Pennsylvania; Allegheny county, Pennsylvania; Erie, Erie county, Pennsylvania; Painesville, Lake county, Ohio; East Liverpool, Columbiana county, Ohio; Gambier, Knox county, Ohio; New Cumberland, Hancock county, West Virginia; Burning Springs, Wirt county, West Virginia.

The gas from wells at several of these localities has been made very valuable for technological purposes:

The use of natural gas at Fredonia was begun in 1821, and was introduced into a few public places, among which a hotel was illuminated when General Lafayette passed through the village. The gas from this well, which was sufficient for about thirty burners, was used alone until about 1858, when another well was drilled, which supplied some two hundred burners. Another well was drilled in 1871 with better success. The average monthly supply of the three combined is about 110,000 cubic feet, of which an average of 80,000 cubic feet per month is consumed for lights. Seven other wells, varying from 50 to 800 feet deep, have been made without success. The area covered by these wells is about one mile in length by one-half mile in width. The supply has not perceptibly diminished since the opening of the wells. (*e*)

At Erie, Pennsylvania, gas-wells have been bored along Mill creek. Some of the deepest of these wells have yielded a dense oil. The Demming well struck gas at about 440 feet under such a pressure that it blew oil to the top of the derrick for twenty-four hours. Many gas-wells have been drilled for private dwellings and manufacturing establishments. For the latter purpose, where large quantities are used, the yield of the wells runs down in a few years. At Painesville, Ohio, gas-wells are bored for private dwellings, and the gas is used often for heating as well as for illuminating purposes. At Rochester, Pennsylvania, and East Liverpool, Ohio, the gas is burned in enormous quantities in glass houses. At Gambier, Ohio, and New Cumberland, West Virginia, the gas is burned in a manner to produce lampblack. The gas of the Burns, Harvey, and Leechburg wells is or has been used in puddling iron. The latter was found particularly valuable in the preparation of the quality of pure rolled iron used for tin plate. The Sheffield well was bored for oil, but instead of oil it has discharged a jet of gas that has burned continuously for five years. In the oil regions the gas from these wells is frequently burned in the open air for no other purpose than to prevent the formation of dangerous explosive mixtures of gas and air.

Bradford and other towns in the oil regions are mainly heated and lighted with natural gas from the oil-wells, and in some instances from wells drilled on purpose to obtain gas. If no oil accompanies the gas, the flame is clear and white, but if oil is present it is red and smoky. Benzine often condenses in the pipes from natural gas, and it is not unreasonable to suppose that, at the enormous pressure under which this gas is held in the oil-sand, the gas is condensed to a liquid. In the Bradford region especially this pressure is much too great to be ascertained by pressure gauges, and has often been made a subject of conjecture, rather than of estimate, as equaling from 2,000 to 4,000 pounds per square inch. Any attempt to ascertain the pressure would be attended with the risk of having the casing and tubing thrown out of the well. The evaporation due to the removal of this pressure produces an extraordinary reduction of temperature. At Sheffield the temperature fell so low that ice formed in the well pipe and finally closed it. The ice was then drilled through 100 feet in depth. When it was pierced, the pressure threw

a *C. Rend.*, lxxv, 154; J. C. Soc., xxv, 884.
b *Ibid.*, lxxv, 115; *Ibid.*, xxv, 885.
c *Ibid.*, lxxv, 270; *Ibid.*, xxv, 885.
d *Ann. de Ch. et de Phys.* (4), xxv, 559; J. C. Soc., xxv, 469.
e Letter of E. J. Crissey, secretary of the Fredonia Natural Gas-light Company, to S. F. P.

the tools and well casing out of the top of the derrick. When a stratum yielding gas is struck in boring, the force of the escaping gas prevents water from reaching the bottom of the well if poured down the side, or even, in some cases, if introduced from a tank through a pipe reaching to the bottom. In most cases by this latter arrangement (which gives the weight of a column of water several hundred feet in height) the gas is "stopped off". The gas has been used in several instances to work an engine for pumping without water or heat by introducing it into the cylinder, precisely like high-pressure steam. In drilling the Roy well, near Kane, Pennsylvania, the gas from a well more than one-fourth of a mile distant was used in this manner. It is very frequently used as a fuel for making steam, and, when there is a surplus, that is burned at the end of a pipe to prevent explosions. The greatest gas-well on record in the oil regions is the Newton well on the Nelson farm, 6 miles north of Titusville. There the gas raised a column of water 100 feet high with a noise that could be heard 2 miles, and when the column burst it threw the water 15 rods each way.

The Bradford Gas-light and Heating Company receive gas into a gasometer from wells near the city. Two sets of pipes pass through the city. One set passes from the wells to the gasometer, and has the same pressure as that on the wells; the other set passes from the gasometer, and delivers the gas under a pressure of about 6 inches of water. Gas is delivered from both sets of pipe; from the high pressure for boilers, etc., and from the other set for use in dwellings. The mains attached to the wells will deliver through the same orifice about ten times the amount delivered from ordinary street mains. The wells are so deep that the friction on the escaping gas is very great, and retards the motion and lowers the pressure as it escapes. The pressure at the wells gradually diminishes. In one case it ran down from an estimated pressure of 1,000 pounds to 6 pounds in five years. When first struck the gas would easily have lifted the casing out of the well, requiring a force of at least 500 pounds per square inch. It was estimated that during the month of January, 1881, 7,500,000 cubic feet of gas reduced to ordinary pressure were delivered in Bradford, where it is almost universally used for heating as well as for illumination. The burning of the superfluous gas at nearly all the wells forms at night great flaming torches, that glare in the darkness from the surrounding hillsides.

Mr. Charles A. Ashburner, of Philadelphia, has described a well which has received the name of the "Kane geyser well". It is situated 4 miles southeast of Kane, on the Philadelphia and Erie railroad. While drilling—

Fresh "water-veins" were encountered down to a depth of 364 feet, which was the limit of the casing. At a depth of 1,415 feet a very heavy "gas vein" was struck. This gas was permitted a free escape during the time the drilling was continued to 2,000 feet. When the well was abandoned, from failure to find oil, and the casing drawn, the fresh water flowed in, and the conflict between the water and the gas commenced, rendering the well an object of great interest. The water flows into the well on top of the gas until the pressure of the confined gas becomes greater than the weight of the superincumbent water, when an explosion takes place and a column of water and gas is thrown to a great height. This occurs at present at regular intervals of thirteen minutes, and the spouting continues for one and a half minutes. On July 31 (1879) Mr. Sheafer measured two columns, which went to a height respectively of 120 feet and 128 feet. On the evening of August 2 I measured four columns in succession, and the water was thrown to the following heights: 108 feet, 132 feet, 120 feet, and 138 feet. The columns are composed of mingled water and gas, the latter being readily ignited. After nightfall the spectacle is grand. The antagonistic elements of fire and water are so promiscuously blended that each seems to be fighting for the mastery. At one moment the flame is almost entirely extinguished, only to burst forth at the next instant with increased energy and greater brilliancy. During sunshine the sprays form an artificial rainbow, and in winter the columns become encased in huge transparent ice chimneys. A number of wells in the oil regions have thrown water geysers similar to the Kane well, but none have attracted such attention. (*a*)

Some of the most remarkable gas-wells that have ever been drilled outside the oil region are the Neff gas-wells near Gambier, Knox county, Ohio. These wells are located on the Kokosing river, a tributary of the Walhonding river, which empties into the Muskingum above Zanesville.

No. 1 well is sunk not far from the line of Knox and Coshocton counties. Such a powerful vein of rich illuminating gas was struck as to cause suspension of all work. From this well immense floods of water, in paroxysms of about one minute interval, are thrown up to a height of 80 to 100 feet. The vein of water was struck, fortunately, at a depth of only about 66 feet, where a large stream was tapped, producing no inconvenience in boring until the gas was struck, when suddenly it was all discharged at regular intervals of not more than one minute. The boring throughout its whole length of 600 feet is filled and discharged, making a most magnificent hydraulic display. It is, however, at night that the grand phenomena of this well are best exhibited. The enormous amount of water, perhaps 10,000 barrels per day, keep the derrick and floor so wetted that the gas can be fired with safety. When this is done, at the instant of paroxysm a sudden roar is heard, and at night the flame is seen shooting up 15 to 20 feet above the derrick, which is 53 feet high. It is a grand sight to see the flame leaping fiercely amid the rushing waters, darting out its fiery tongues on every side; now rolling above the most powerful part of the jet like balls dancing on a fountain, and now, with an intensely bright flame, leaping suddenly down the column and running along the floor, and illuminating, as with burning liquid naphtha, which is undoubtedly thrown out with the water, the whole forest scenery around as a magnificent spectacle. When the derrick was covered with ice the gas escaping from the well was frequently ignited, and the effect, especially at night, of this fountain of mingled fire and water shooting up to the height of 120 feet through a great transparent and illuminated chimney is said to have been indescribably magnificent. (*b*)

A phenomenon (called a gas volcano) that has been observed in the valley of the Cumberland, in southern Kentucky, near Burkesville, is thus described. In a private communication Dr. J. S. Newberry writes:

This name is given to explosions of gas accumulated under the flaggy rocks of the Hudson River group in the valley of the Cumberland and its tributaries. I have visited localities where explosions have occurred, but have never witnessed one myself. They result from the confinement of gas generated below under impervious strata of rock, the pressure ultimately becoming sufficient to throw off the superincumbent mass of rock, earth, water, etc. These explosions are not very uncommon in the valley of the Cumberland, and they are well known to the inhabitants.

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a Jour. Frank. Inst., cviii, 347. *b* Prospectus of the Neff Petroleum Company, 1866.

SECTION 2.—USE OF NATURAL GAS IN THE MANUFACTURE OF LAMPBLACK, ETC.

The gas of the Neff and other wells is largely utilized for the production of lampblack. This black is of very superior quality, and when first produced and thrown upon the market commanded as high a price as 75 cents per pound, but the production was very soon increased so largely in comparison with the demand that the price is now only about 15 to 20 cents per pound. Concerning the production of lampblack from natural carbureted hydrogen, a writer in Dingler observes as follows: (*a*)

It is known that gases escaping from the soil of some of the oil districts of Pennsylvania (compare 1878, 228, 534) is prepared for illumination and heating purposes (1877, 224, 552). P. Neff now produces from the same by imperfect combustion an excellent lampblack, which he brings into market under the name of "*diamond black*". This gas flows from two wells which are bored at Gambier (Knox county, Ohio), in the vicinity of the mouth of the Kokosing. According to J. R. Santos (*Chemical News*, 38, 94, 1878), it has the following composition:

	Per cent.
Marsh-gas	81.4
Ethylene	12.2
Nitrogen	4.8
Oxygen	0.8
CO	0.5
CO_2	0.3
	100.0

Neff burns daily with 1,800 burners of peculiar construction almost 8,000 cubic meters of gas and obtains from it 16 per cent. of lampblack. The specific gravity of this lampblack is, according to Santos, 1,729 at 17° C. Dried at 200° an elementary analysis gives:

	I. Per cent.	II. Per cent.
C	96.041	96.011
H	0.736	0.747

By means of Sprengel's air-pump the gas is pumped out, having the following composition:

CO	1.387
CO_2	1.386
N	0.776
H_2O	0.682

Besides, 0.024 per cent. of a bright yellow hydrocarbon soluble in alcohol, and which boils at from 215° to 225°, is obtained, which is probably impure naphthaline. The small quantity of ashes consisting of the oxides of iron and copper comes from the burners. The united composition of diamond black is accordingly as follows:

	Per cent.
C	95.057
H	0.665
N	0.776
CO	1.378
CO_2	1.386
H_2O	0.682
Ashes	0.056
	100.000

The black is consequently very pure, and in any case is well adapted for fine printers' ink and the like. It is also used in the preparation of lithographic ink.

At New Cumberland, Hancock county, West Virginia, Messrs. Smith, Porter & Co. use natural gas for burning fire-brick. The gas from one well furnishes fuel for nine brick kilns, three engines, and ten furnaces in the drying house, with fuel and lights for several dwellings, besides a large excess that is burned at the end of an escape pipe. They produce 55,000 brick daily.

SECTION 3.—GAS FROM CRUDE PETROLEUM, PARAFFINE OIL, AND RESIDUUM.

A large number of patents have been taken out for processes and apparatus for the manufacture of illuminating gas from crude petroleum and the dense products of its manufacture. The general principle upon which all of these processes depend for operation consists in a distillation of the materials at a temperature sufficiently elevated to crack the petroleum compounds into gaseous products. The "gas oil", which is petroleum deprived of its naphtha, is conducted into a retort previously heated to a red heat. The method of heating the retort, the manner of distributing the fluids, and the purification of the gas from the undecomposed petroleum and tarry matters, are all subject in the different patents to differences of arrangement, but the underlying principle of destructive distillation is fundamental in all of them. This method of preparing illuminating gas is quite extensively used for lighting large manufactories and villages and small towns. It is especially valuable for these purposes on account of the comparative simplicity of the apparatus and process of manufacture and the purity of the product. The gas prepared by this method is particularly free from the ammonia and sulphur compounds that contaminate gas prepared from coal.

a Dingler, ccxxxi, 177.

Section 4.—GAS FROM NAPHTHA.

Gas is also prepared by the destructive distillation of petroleum naphthas and benzine. One of the methods of operating this process is thus described: A still holding 40 barrels of naphtha contains a coil of 2-inch pipe; steam passes through the coil, volatilizing the naphtha, the pressure carried on the still being on an average about one-half inch. The vapor passes to three benches, of three retorts each, by a 3-inch pipe; 1½-inch branches to each retort are tapped into the side of this mouth-piece, connecting with a 6-inch cast-iron pipe, which lies inside of the retort to within 1 foot of the back, and is open at the back end, but plugged in front with a clayed stopper. The vapors circulate through the 6-inch pipe to the back end of the retort and return forward and up the stand-pipes, which are 6 inches in diameter. These retorts are heated to dull redness. During this transit the vapors of naphtha are converted into gas and pass through a submerged U-shaped condenser, 18 inches in diameter, lying in a tank with sufficient inclination for a drip. An air-pump is used to preserve an exhaust of about 3 inches, from which the gas passes to a station meter and "mixer". At every revolution of the station meter 42 per cent. of air is drawn in by a reverse drum on the same spindle, and is mixed with the gas, which thence passes to the holder. The introduction of air is not necessary, as the gas can be burned with a suitable burner; but the gas thus prepared is very rich, and the air is introduced to reduce its quality to the average standard of 15 or 20 candle-power. It will be observed that all apparatus for purifying the gas is dispensed with, the gas being entirely free from all deleterious sulphur and ammonia compounds. The only residue in this process is a small quantity of heavy oil, apparently a residue from the cracking of the benzine.

Section 5.—CARBURETORS.

The idea of saturating illuminating gas with the vapors of volatile hydrocarbons for the purpose of increasing its illuminating power was entertained long before the discovery of petroleum in commercial quantities.

Lowe patented a process in 1841, and alluded to it in a general way in a previous patent of 1832, the claim in which is so comprehensive that, if valid, it would render doubtful all subsequent patents. (*a*) Mansfield also claimed the application of atmospheric air as a vehicle for the vapor of very volatile hydrocarbons in such a manner that the "vaporized air" might be burnt like ordinary coal-gas. (*b*)

As early as 1856 Longbottom attempted to prepare illuminating gas by passing air through benzole, ether, or oil of turpentine. (*c*) These appear to be the earliest attempts at carburation. These machines were never made a practical success, however, until the distillation of petroleum furnished volatile hydrocarbons in commercial quantities. The low price at which these products could be obtained after petroleum became extensively produced led to the invention of a large number of machines in a great variety of form and principle of construction. The number patented in England, France, Germany, and the United States prior to 1880 must be in the neighborhood of 1,000. The first patents that were issued were for inventions that produced a partial or a complete saturation of the gas or air without in any manner controlling the evaporation or the temperature. The result of the operation of these machines was invariably an overcharging with vapor in warm weather or when the apparatus was first put in action, causing subsequent condensation of the vapor, followed by undercharging as the naphtha was distilled and the residue became less volatile, and as it also was rendered more dense in consequence of the reduction of temperature resulting from the evaporation. Evaporation was induced and rendered more constant and rapid by the construction of a sort of labyrinth through which the gas or air was forced. The tank containing the naphtha was made shallow and of large diameter, and curtains of flannel were so arranged that the upper border of the curtain was securely fastened to the under surface of the cover of the tank and allowed to hang freely, dipping into the naphtha below. As a result, the gas was forced to pass through the spaces between these curtains, and a great evaporation and absorption of the naphtha vapor by the gas followed. This method of carburation, while very effectual, was still open to the objections above made, and did not furnish uniform results; but the difficulty was removed by an invention by which the tank in which the naphtha was being distilled was submerged in a wooden tank of water. The great latent heat of water caused it to give out heat, equalizing the temperature, producing a uniform distillation, and consequently a uniform partial saturation of the gas or air. This contrivance may be said to have rendered the carbureting of air a success, and a large number of machines have been constructed upon this principle. The general arrangement of the apparatus has been a wooden tank, sunk in the ground outside the building and below the frost. In this tank the receptacle for the gasoline is placed, and the intervening space is nearly filled with water. At this depth the water preserves nearly a uniform temperature at all seasons, and from its large volume it compensates the gasoline for its loss of heat due to evaporation, and keeps both the temperature and the distillation uniform; consequently the amount of combustible material supplied the current of air is uniform. This current is forced through the labyrinth by an air-pump worked by a heavy weight, and placed in the basement of the building to be lighted. This form of carburetor is entirely free from the grave defect of starting at the beginning of the evening with an excessive evaporation and ending at 10 or 12 o'clock with an insufficient evaporation. The distillation proceeds uniformly, and changes in quantity gradually, the difference being perceptible only after the machine has been in operation several weeks or months. The gradual fractional distillation results in the accumulation of a residue in the labyrinth too dense for evaporation with

a *Jour. Soc. Arts*, ii, 503. *b* *Ibid.*, 520. *c* Jahresbericht, 1856, p. 422.

sufficient rapidity to properly carburet the air, and is, consequently, attended with diminished illumination. Many attempts have been made to remedy this defect, in which great success has been attained by a remarkable invention of very recent date. This machine is called the metrical carburetor, and is used for carbureting either gas or air. The name designates a peculiar feature of the instrument—that it *measures* the amount of carbureting fluid to either the gas or the air; hence there is never an excess of carburation, no fractional evaporation, and no condensation of liquid in pipes. One and one-half to 2 gallons of light naphtha are measured to 1,000 cubic feet of ordinary street gas, or 3 to 6 gallons of gasoline to 1,000 cubic feet of air, according to the purpose for which the gas is to be used.

The carburation of gas and air has been made the subject of many elaborate researches. Prominent among those who have conducted them is the late Dr. Henry Letheby, medical officer of health to the city of London, who, as early as 1861, reported that—

With regard to the carbureting process we are of opinion, from the data obtained by the laboratory experiments quoted in the report to the commission of the 30th of July last and the experiments made on the public lamps in Moorgate street during the months of June and July last, that the process of carburation appears to be capable of economizing the use of gas in the public lamps to the extent of from 40 to 50 per cent. This conclusion is founded on the assumption that the best quality of naphtha is to be used, namely, a naphtha which will give to the gas continuously a proportion of about 10 grains of volatile hydrocarbon to each cubic foot of gas, these being the average results of the laboratory experiments. (*a*)

The following comparative tests were published in 1879 in *Engineering*, but the author is not mentioned:

Practical test.—Barometer, 29.8; temperature, 56°; the weight of gasoline, 655 grains to water 1,000 grains; therefore one gallon of gasoline = 45.850 grains. The air was simply aspirated at the rate of 6 cubic feet per hour through an ordinary chemist's wash-bottle, and each cubic foot took up 735 grains, illuminating gas of 17.10 candles taking 585 grains.

$$\begin{array}{ll} & \text{Grains.} \\ \text{1,000 cubic feet of air} = & 735.000 \\ \text{1 gallon of gasoline} \quad = & \overline{\ \ 45.850} \end{array} = 16.0 \text{ gallons of gasoline per 1,000 cubic feet of air.}$$

$$\begin{array}{ll} \text{1,000 cubic feet, 17.10 gas} = & 585.000 \\ \text{1 gallon of gasoline} \quad = & \overline{\ \ 45.850} \end{array} = 12.7 \text{ gallons of gasoline per 1,000 cubic feet of gas.}$$

One thousand cubic feet of air, after being carbureted, = 1,320 cubic feet; and 1,000 cubic feet of 17.10 gas, after being carbureted, = 1,270 cubic feet.

Specific gravity test.—The time required to pass equal volumes of air, gas, carbureted gas, and carbureted air, under equal pressure, through the same aperture (Shilling's test), was: air, 88 seconds; gas, 58 seconds; carbureted gas, 90 seconds; carbureted air, 104 seconds.

$$\text{Gas, } \frac{58^2}{88^2} = 434 \text{ to air 1,000.}$$

$$\text{Carbureted gas, } \frac{90^2}{88} = 1,045 \text{ to air 1,000.}$$

$$\text{Carbureted air, } \frac{10}{88} = 1,396 \text{ to air 1,000.}$$

Photometric test.—Test on Hartley's improved photometer, 15-hole argand burner (old standard), 7-inch by 2-inch chimney, consuming 2.4 cubic feet per hour of carbureted gas, = 14.59 standard candles; reduced to the standard of 5 cubic feet, = 37.78 standard candles.

Also, with No. 1 steatite bat-wing, consuming 2.40 cubic feet per hour, = 18.63 standard candles; reduced to the standard of 5 cubic feet, = 38.83 standard candles; 3.48 cubic feet per hour of carbureted air consumed through argand burner = 16.52 candles; reduced to the standard of 5 cubic feet, = 23.70 candles.

Durability test.—The durability of 1.10 cubic feet 4-inch flame:

	Min.	Sec.
Gas	5	45
Carbureted gas	16	38
Carbureted air	11	24

Various forms of machines were experimented on, viz, cylinders containing lamp cotton, sponge, felt, and wood carbon. They are all useless and obstructive, nor do they yield so high or regular a light as air aspirated or exhausted through gasoline and charged into a gas-holder, from which it is supplied ready for use at the burner when required.

Upon this the editor of the *Journal of the Franklin Institute* comments as follows:

Two great objections still exist to the use of these machines, viz, the impossibility of storing large quantities of gasoline without the risk from fire to property in the neighborhood; and, secondly, that if the pressure becomes excessive the flame from the burner will be blown out, and terrible explosions, resulting in loss of life, have followed in consequence. The increase in the illuminating property of coal-gas as ordinarily furnished, when passed through these machines, is very great, and the flame, also, is not liable to be blown out with increased pressure; and a wide field seems to be open in this direction if all danger from fire in the carbureting of the gas could be done away with. (*b*)

The value of the metrical carburetor will be appreciated when it is understood that it gives a degree of carburation perfectly satisfactory for gas with $1\frac{1}{2}$ to 2 gallons of light naphtha to 1,000 cubic feet of gas, and for air with 3 to 6 gallons of *gasoline* to 1,000 cubic feet of air. Moreover, this quantity is *measured* to the gas or air with great accuracy, is all immediately absorbed, and, as no supersaturation ever occurs, no condensation ever takes place in the pipes, and no "running down of the light" is ever due to cold nights or distillation of the gasoline. In regard to economy, safety, and perfect operation this metrical carburetor far excels all others hitherto invented.

a Jour. Soc. Arts, x, 87. *b* Jour. Franklin Institute, cvii, 404, 1879

CHAPTER IV.—THE USE OF PETROLEUM AND ITS PRODUCTS AS FUEL.

SECTION 1.—THEORETICAL CONSIDERATIONS.

The excessive production of petroleum in some localities, and the scarcity of coal and wood in others where petroleum abounds, has led to a large number of experiments in the use of petroleum as fuel. The theoretical consideration of its value as fuel was made the subject of elaborate investigations at an early date. In 1864 R. Mallett stated that—

The theoretical evaporating power of American petroleum may be ascertained as follows:

$$\begin{array}{r} C\ 86 \\ H\ 14 \\ \hline 100 \end{array} = 18.06 \text{ kilograms.}$$

For—

$$\begin{array}{l} C\ 0.86 \times 8.080 = 6948 \\ H\ 0.14 \times 34.462 = \underline{4824} \\ \qquad\qquad\qquad 11772 \text{ heat units.} \end{array} \qquad \frac{11772}{652} = 18.06$$

Regnault's formula is 65.2 heat units for the evaporation of 1 kilogram of water at 0° to steam at 150°. (*a*)

In 1869 Henri St. Claire De Ville conducted an elaborate research upon the calorific power and physical peculiarities of petroleum. His results are given in the following table:

Locality of the oils.	Specific gravity.	Calorific power.
1. Heavy oil from White Oak, West Virginia; well, 135 meters deep; lubricating oil.	0.873	10.180
2. Light oil, from Burning Springs, West Virginia; well, 220 meters deep; illuminating oil.	0.8412	10.223
3. Light oil, from Oil creek, Pennsylvania; well, 200 meters deep; illuminating oil.	0.816	9.963
4. Heavy oil, from Ohio	0.887	10.399
5. Heavy oil, from the Plummer farm, Franklin, Pennsylvania; well, 200 meters deep; lubricating oil.	0.886	10.672
6. American petroleum, as offered for sale in Paris, probably from Pennsylvania.	0.820	8.771
7. Heavy coal-oil, from the Paris Gas Association	1.044	8.916
8. Petroleum from Parma, near Salo	0.786	10.121
9. Oil from Java, commune Dandang-Llo, district Timaacon, residency Pembang.	0.923	10.831
10. Oil from Java, commune Tjibodas-Fanggah, district Madja, residency Cheribon.	0.823	9.593
11. Oil from Java, commune Gogor, district Kendong, residency Karabaya.	0.972	10.183
12. Oil from Bechelbronn, upper Rhine, distilled	0.912	9.708
13. Oil from Bechelbronn, raw	0.892	10.020
14. Oil from Schwabweiller, lower Rhine	0.861	10.458
15. Oil from east Galicia	0.870	10.005
16. Oil from west Galicia	0.885	10.231
17. Raw schist oil, from Vagnas, Ardèche	0.911	9.046
18. Raw schist oil, from Autun, manufactured by Champeaux, Bazin & Radary.	0.870	9.950
19. Heavy *Kiefernharz* oil, from Mount de Marzan	0.985	*10.081

* *C. Rendus*, lxvi, 442; lxviii, 349; C. N., 1869, 237.

In 1871 he examined the petroleums of the Russian empire from the neighborhood of Baku, on the Caspian sea, and obtained the following results: No. 1 was crude naphtha from the Balchany wells, specific gravity at 0°, 0.882; No. 2 was residuum from the Baku stills, specific gravity 0.928; No. 3 was black oil from the Weyser refinery at Baku, specific gravity 0.897; No. 4 was light oil of Baku, specific gravity 0.884; No. 5 was heavy oil of Baku, specific gravity 0.938. On distillation they afforded:

Temperature.	1.	2.	3.	4.	5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Volatile at 100° C	1.0	....	....	....	....
Volatile at 140° C	....	....	....	2.7	....
Volatile at 160° C	5.0	....	....	7.0	....
Volatile at 180° C	9.3	....	....	13.3	....
Volatile at 200° C	14.0	....	2.3	....	1.0
Volatile at 220° C	15.3	....	....	19.0	1.3
Volatile at 240° C	....	1.0	8.0	23.3	1.7
Volatile at 260° C	29.0	2.3	14.0	29.3	3.0
Volatile at 280° C	37.0	4.3	22.3	36.7	6.0
Volatile at 300° C	41.3	7.7	33.7	73.3	9.7

COMPOSITION AS GIVEN BY ANALYSIS.

Hydrogen	12.5	11.7	12.0	13.6	12.3
Carbon	87.4	87.1	86.5	86.3	86.6
Oxygen	0.1	1.2	1.5	0.1	1.1
	100.0	100.0	100.0	100.0	100.0

a Pract. Mech. Jour., March, 1864, p. 314; Dingler, clxxii, 71.

From these data their calorific power was calculated and compared with that obtained by experiment in the petroleums marked 4 and 5. The results are thus given in calories:

	1.	2.	3.	4.	5.
Calorific power, calculated	11.370	11.000	11.060	11.660	11.200
Calorific power, observed	(11.070)	(10.700)	(10.760)	11.460	10.800

Numbers 1, 2, and 3 were calculated from the results in 4 and 5. These results show the Baku oils to be superior to those of America and Europe for heating purposes. (*a*)

In 1877 K. Lissenko stated that—

Some forms of petroleum that yield a less amount of heat on combustion than that calculated are regarded as containing hydrocarbons of the series C_nH_{2n+2}, accompanied by small quantities of non-saturated hydrocarbons. (*b*)

Later, M. Berthelot has shown in a research upon the gaseous hydrocarbons that the heat of combustion of an hydrocarbon is not always equal to that of its elements. The variation is least in the case of the saturated hydrocarbons C_nH_{2n+2}. (*c*)

As no two petroleums from different localities are alike in composition, these researches indicate that considerable variation exists in the heating power of different petroleums, and that practically their heating power is considerably less than would be calculated from their elementary composition.

Section 2.—PETROLEUM AS A STEAM FUEL.

The employment of petroleum as a steam fuel has been the subject of many experiments and much controversy. From a careful survey of the subject I conclude that no important practical difficulty has been anywhere encountered where for any reason petroleum has been a more desirable fuel than other material. Petroleum has always been burned for steam fuel more or less in the oil regions of Pennsylvania. All sorts of experiments have been made there to burn the crude oil, both pure and mixed, with steam. Mr. D. A. Wray, on Oil creek, filled with crude oil, at 50 cents per barrel, an 8-horse boiler, with safety-valve attached. He fired up under it as if it was filled with water, and burned the vapor as if it were gas. The arrangement worked well until the spaces between the boiler tubes became choked with coke. This deposit of coke from distillation of the oil has been found to be the chief practical difficulty, and has usually been avoided by injecting steam through the escaping oil in such a manner as to completely volatilize it. Another practical difficulty observed by Mr. Wray was explained by him as in accord with an observation of Tyndall that the flame of a Bunsen lamp is intensely hot to objects immersed in it, but that it radiates comparatively little heat. Mr. Wray has observed that all successful contrivances for burning petroleum must distribute the flame *upon* the surface to be heated, and not beneath it. Inattention to this condition is the cause of many unsuccessful attempts to generate steam by the use of crude petroleum. It is impossible that I should attempt to describe the great number of apparatus devised for burning the crude oil, many of which are entirely adequate. The successful use of the oil for years in stationary engine boilers has demonstrated the absence of all serious practical difficulties. The questions of economy and safety appear to have determined that for *general* use it is not a desirable fuel, while in special cases its use has been attended with complete satisfaction.

Mr. William T. Scheide has communicated to me the following results obtained by the United Pipe-lines:

The oil was burned with a steam jet under four stationary boilers (60-inch shells 14 feet long, with 83 3-inch tubes), and the steam furnished a Worthington compound duplex pump doing an *actual* work of about 200 horse-power. (The indicated horse-power would probably be about 225 to 250 horse-power.) These boilers and this pump use as nearly as possible 4.54 pounds of bituminous coal per horse-power of *work done* per hour. Using this average, which is pretty well determined, as a basis, 1 ton of 2,000 pounds of this coal is equal as fuel to either 3.94 or 4.13 barrels of 42 gallons each of oil. The experiment was not conducted as it should have been, and there is a question as to the pressure against which the pump worked, which accounts for the difference in the estimate. I think it may be stated, however, that 4 barrels of oil would be required to furnish the equivalent of a ton of good bituminous coal if the oil is burned with a steam jet. With an air jet I look for better results.

It has also been very thoroughly tested for use on steam vessels. In 1868 the then Secretary of the Navy reported that the appropriation of $5,000 for testing petroleum as a fuel on steam vessels had been expended on a series of elaborate experiments at the New York and Boston navy-yards.

The conclusion arrived at is, that convenience, comfort, health, and safety are against the use of petroleum in steam vessels, and that the only advantage thus far shown is a not very important reduction in bulk and weight of fuel carried.

At Woolwich experiments were made with naphthaline, creosote, residuum, tar, and grease, but nothing proved satisfactory except pure American petroleum and "clear British shale oil". Comparative tests showed the—

	Per cent.
Highest evaporation of water per pound of coal	7.33
Lowest evaporation of petroleum	12.02
Highest evaporation of petroleum	13.00

On July 31, 1869, a train arrived safely in Katschujan, 81 versts from Charkoff, whose engine was heated with raw naphtha (petroleum) instead of coals. The honor of the invention is ascribed to the mining engineer, Portski.

a *C. Rendus*, lxxii, 191; lxxiii, 491.

b Russian Chem. Soc., June, 1877; C. N., xxxv, 180; J. C. S., xxiv, 453.

c *C. Rendus*, xc, 1240; J. C. S., xxxviii, 786.

Two engines on the Strasbourg line, fitted in 1870 with M. Deville's furnaces, burn from 3½ to 5 kilograms of oil to every kilometer traversed, or say 8—12 pounds to two-thirds of a mile. The oil is completely burned, and no sulphur is observed in the atmosphere of the tunnels.

Petroleum has also been used with entire success upon steamers and locomotives in the United States. While all of these experiments and practical tests show that petroleum can be used on locomotives without difficulty, and perhaps with some elements of superiority over other kinds of fuel, it cannot be affirmed that it is as yet so economical as to lead to its use in the face of the very grave and unquestioned elements of danger attending it. Coal in the United States is cheap, plentiful, and safe, but on the Caspian sea it is rare and costly. This fact constitutes a sufficient reason why persistent and successful efforts to burn petroleum and residuum on the steam vessels that traverse that sea should have led to its almost exclusive use for steam purposes. The following concise statement explains the method of its use:

An apparatus has been devised for the utilization of petroleum as fuel in steam navigation, and its application for this purpose in central Asia has, it is reported, been attended with results that are considered very satisfactory, such fuel also occupying much less space than the amount of coal necessary to produce a similar effect.

With the old-fashioned boilers in use—with a central opening running longitudinally—no modification, it is stated, is necessary for the employment of the fuel in question. A reservoir containing some hundred pounds' weight of the refuse, "astalki," is furnished with a small tube, bearing another at its extremity, a few inches long and at right angles with the conduit. From this latter it trickles slowly. Close by is the mouth of another tube connected with the boiler. A pan containing tow or wood saturated with astalki is first introduced to heat the water, and on the slightest steam pressure being produced a jet of vapor is thrown upon the dropping bituminous fluid, which is thus converted into spray; a light is applied, and then a roaring deluge of fire inundates the central opening of the boiler. It is a kind of self-acting blow-pipe.

The volume of fire can, it is stated, be controlled by one man, by means of the two stop-cocks, as easily as the flame of an ordinary gas jet. Mention is made of a steamer of 450 tons and 120 horse-power on this principle, 30 pood per hour of astalki being burned to obtain a speed of 13 nautical miles in that time; and as 1 pood is about 33 pounds, and costs on an average about 10 to 12 cents, or about \$60 for a twenty hours voyage at full speed.

The use of petroleum in Russia for steam fuel on both locomotives and steam vessels has been very fully discussed by T. Gulichambaroff in the *Gornii Journal* for 1880. He says that—

In the Caucasus the refuse of the distilleries is used as fuel, which in 1874 could be had for nothing. In 1875 the price was 3*d.* per barrel of 20 poods (720 pounds); in 1876 it rose to 1*s.*, and 1877 to 2*s.*; in 1879 the price had reached 5*s.* 3*d.*, while raw petroleum at the same time was 10*s.* Attention is now being directed to the use of raw petroleum, against which there is a standing prejudice on account of the possibility of explosions. Any liability to explosion is easily removed by exposure to the air for a few days. On the Balachanskoi railroad the locomotives are fired with raw petroleum, which is poured into the tender direct from the springs; yet there has never been an accident. The author has seen burning logs quenched with petroleum without setting it on fire, and spontaneous combustion is impossible, as the oils do not absorb oxygen. At present all the steamers on the Caspian sea use liquid fuel, 4.5 to 4.9 pounds per horse-power; 1,080 pounds of naphtha (petroleum) is found to be equal to 343 cubic feet of oak wood. The use of petroleum by injectors and its freedom from sulphur present great advantages over any other form of fuel. (*a*)

The action of hydrocarbons at a red heat with steam has been investigated by M. Coquillion. He shows that steam assists the dissociation of the hydrocarbons, producing at the same time a fall of temperature which is added to that produced by the reduction of CO_2 to CO. (*b*)

As already stated, the use of petroleum for steam fuel is determined by its cost relative to other kinds of fuel. With the low price of petroleum at Baku and the absence of wood and coal on the steppes of Russia and the shores of the Caspian sea, there can be no question that petroleum is the cheapest and best steam fuel to be had in that region. But in the United States the question lies between petroleum and anthracite coal for ocean steamers and bituminous coal on the western rivers. I think no one would now question the ease and efficiency with which petroleum can be burned in several forms of apparatus lately invented, nor can it be denied that it is less bulky than coal and more conveniently handled; but that it is a safe material to use on ocean passenger steamers as compared with coal cannot be maintained. Moreover, the claim that is made that much less stowage is required is not found to hold to any extent against anthracite coal. A ton of anthracite requires 48 cubic feet and a ton of petroleum requires 44 cubic feet. The difference is inconsiderable. As the question is at present stated, I do not look for any considerable increase in the use of petroleum for steam purposes in the United States.

Section 3.—PETROLEUM AND ITS PRODUCTS IN THE MANUFACTURE OF IRON.

The natural gas of the oil-wells has been successfully used in the manufacture of iron in the vicinity of Pittsburgh, Pennsylvania. Messrs. Spang, Chalfant & Co., whose works are at Sharpsburg, brought the gas in a 6-inch pipe to their works from wells near Saxonburg, Butler county, a distance of 17 miles. They use it for puddling and heating and for making steam. Messrs. Rogers & Burchfield placed their works at the wells on the Kiskimenitas, a tributary of the Allegheny river. They use it in an ordinary reverberatory furnace by bricking up the bridge and introducing the gas in pipes with a blast. It has been remarked that the quality of the iron is something wonderful; with ordinary gray coke pig-iron sheets for tin-plate equal to those from the best charcoal iron are made at a cost of \$50 per ton less.

a Proc. London Inst. Civil Engineers, lxiii, 408.

b C. *Rendus*, No. 19, 1878; C. N., xxxvii. 262.

A large number of processes have been invented and patented for using raw petroleum in the manufacture of iron. Of these the Eames process appears to have been the most successful, and to have had the most satisfactory trial.

At the Laclede iron works, in Saint Louis, experiments have been instituted under what was known as the "Whipple and Dickerson", or "Ambler process". These experiments were unsatisfactory, but in what respect I have not been able to ascertain. Experiments were also made at the Chatham dockyard, in England, which were in many respects highly successful, particularly with reference to the fine quality of iron produced.

The Eames process has been put into practical operation both in Titusville, Pennsylvania, and in Jersey City, opposite New York. Why it has not proven a commercial success I have not been able to learn. Competent judges having an interest in the success of the establishment at Titusville bear testimony to the extraordinarily fine quality of the iron produced from scrap and refuse of the most forbidding character. The process has been made the subject of a most careful and exhaustive examination by Professor Henry Wurtz, of New York, and Professor R. H. Thurston, of the Stevens Institute of Technology, Hoboken, New Jersey. The cut, Fig. 57, represents the apparatus in section. It consists of an ordinary reheating furnace with the "generator" and steam-boiler attached. The generator, which is the peculiar feature of the apparatus, is shown at A. It consist of a cast-iron vessel, from the sides of which shelves project alternately. The oil, entering from a reservoir at D, trickles over these shelves, from which it is swept by a jet of steam superheated to incandescence, entering the generator at E from the coil B. The amount of oil required for this furnace, which is capable of working charges of 3,000 pounds and making steam for the rollers besides, is a maximum of 30 gallons or 200 pounds per hour. The trickling oil is met by the jet of steam moving in the opposite direction, and is at once completely vaporized under a pressure of about 10 pounds and is carried into the furnace C. Air enters at F, and, mingling with the mingled vapor and steam, passes through the former bridge at H, and burns within the furnace in a long solid sweep of flame, which escapes from the furnace at I, and returns, after passing beneath the boiler, through the boiler flue to the stack. The old bridge of the furnace is completely bricked up excepting at H, where a space extends across the furnace, closed only by fire-bricks placed on end, and it is found that if this "combustion chamber" has a horizontal thickness of more than 18 inches the fire-bricks are *fused.*

I quote the language of Professor Wurtz's memoir respecting the working of the apparatus described:

It is quite easy to determine with precision with the arrangements at Jersey City the relations of consumption of oil to iron produced, and time, labor, and material occupied in any special case. The oil was fed from a tank, sunk in the ground, which had a horizontal section throughout of 4 feet square. Each inch in depth, therefore, corresponded to 2,304 cubic inches, or closely enough to 10 United States gallons of 231 cubic inches. By gauging with a graduated rod each hour, therefore, the hourly consumption of oil was readily followed up. It was thus determined by me that, starting with a cold furnace and boiler full of cold water, 45 minutes was a maximum time, with oil fed at the rate of 30 gallons per hour, or 22.5 gallons in this time, to bring the whole fire space to a dazzling white heat. Six piles of boiler scrap, averaging 500 pounds, or 3,000 pounds in all, being then introduced, 35 minutes more at the same rate of consumption not only brought the piles to a high welding heat, but raised the steam in the boiler to 90 pounds pressure, being that required to operate the rolls. The time required after the furnace was heated and steam up for each charge of 3,000 pounds averaged at most 80 minutes, and as the brick-work became heated throughout it was apparent that the feed of oil might be somewhat diminished. Thus in a working day of ten hours just seven such charges could be worked off, averaging 2,500 pounds of rolled iron each; total, 8 tons per day of boiler-sheet from one such furnace, with an average consumption, as a maximum, of 30 gallons (200 pounds) of oil per hour, or 300 gallons (2,000 pounds) in all. To this must be added, however, the fuel used under the generator and small supplementary boiler, which together was 500 pounds per day. It is admissible that one generator and one small boiler will operate several furnaces, the inventor says 5; if we say 4, it will diminish the small addendum of cost.

As to working this furnace with coal, it was ascertained from the testimony of the operators that, by keeping up the fire all night, so that a heat could be had at a reasonable time in the morning, the maximum product of finished sheet might be, with superior work, allowing 90 minutes for each heat, 6 tons, with a consumption of at least $5\frac{1}{2}$ tons of coal = 12,320 pounds, or 2,053 pounds of coal per ton. (*a*)

I have omitted Professor Wurtz's estimates of comparative cost, as any one interested can readily make them to suit the prices of coal and crude oil in his own locality.

SECTION 4.—STOVES.

During the last few years stoves in great variety have been contrived in which some of the products of petroleum are consumed as fuel. Practically they may be divided into naphtha and kerosene stoves. In reference to the use of the naphtha stoves I have nothing to say, excepting that their manufacture, sale, and use ought to be prohibited by law. I need not repeat here the facts and arguments already brought forward to show why they are dangerous to persons who use them and to the communities in which those persons live. In spite of all that has been written and spoken on this subject, a vast number of them is sold every year. The apparent apathy of the public in reference to this matter is shown by the fact that after the terrible fire in the New York tenement houses in January, 1881, caused by the careless use of gasoline in some sort of plumbers' apparatus, Commissioner Gorman said to a *New York Herald* reporter—

That he had examined the law regarding the use of gasoline, and he found no statute that could prevent its being used as a heating and illuminating agent. Section I, chapter 584, of the laws of 1871 provided that "no refined petroleum, kerosene or other burning fluid shall be used for heating or illuminating purposes in any dwelling, house, store, shop, restaurant, car, coach or other vehicle, which

a Am. Chem., vi, 94.

shall evolve combustible vapor at a temperature below 100° Fahrenheit". Now, had the law not been repealed, it would have prevented plumbers using gasoline for heating purposes. The law, as I have read it to you, was, however, repealed by section 4, chapter 742, of the laws of 1871, which reads "that no refined petroleum, kerosene, coal or similar oil, or product thereof, shall be used for illuminating or heating purposes which shall emit an inflammable vapor at a temperature below 100° F., or shall be kept for sale or stored within the corporate limits of the city of New York". (*a*)

On the 1st of June following 27 barrels of gasoline lying on the platform of the Consolidated Railroad freight-house in Springfield, Massachusetts, took fire from some accidental cause, and after a part of them were supposed to be extinguished several of the remainder exploded and injured about 40 persons more or less seriously. December 27 following the steamer West Point exploded and burned at West Point, Virginia. Nineteen persons were killed and a number badly injured. Her "cargo was made up of miscellaneous freight, among which were several hundred barrels of oil, sixty of which were *gasoline*". These are some of the gasoline accidents for one year, and yet there is no general legislation to prevent gasoline from being used in lamps and stoves and from being carried as common freight except section 4472 of the Revised Statutes of the United States, quoted on page 236.

The kerosene stoves are being brought to a great degree of perfection, and are found to be very useful. Of the several different manufacturers who are seeking the patronage of the public I am not disposed to select any as making in all respects an article superior to all others. These stoves act best with high-test oil, and are therefore safe. Their healthfulness depends upon the manner in which they are used. It is claimed that one of these stoves with two burners discharges an amount of carbonic acid into the atmosphere of a room equal to the respiration of 2½ persons. I have not examined the merits of this statement; but, assuming the statement to be correct, it is a sufficient reason why the most thorough ventilation should be urged upon those using these stoves. Very few are used under circumstances that admit of the removal of the products of combustion from the apartment, and when one is used in a small room occupied by two persons the contamination of the air amounts to that caused by the constant occupation of the room by from four to five persons. When to this unavoidable source of impure air is added the sulphurous acid and half-burned products of the combustion of poor and cheap oil, the use of petroleum stoves cannot be recommended as conducive to health. Yet they are cheap and convenient, are used by tens of thousands, and their use is increasing.

SECTION 5.—MISCELLANEOUS APPLICATIONS OF PETROLEUM PRODUCTS FOR HEATING PURPOSES.

Petroleum and nearly all of its products and natural gas are used in glass houses for producing high temperatures and flames free from soot and other materials that would injure the glass. At Wheeling, West Virginia, one of the largest glass houses uses benzine for producing the intense heat of the "glory holes", and other houses use natural gas for the same purpose. Throughout the oil regions natural gas is largely consumed in the towns for heating dwellings and culinary purposes. It is used with a large Bunsen burner, from which the flame is projected into an ordinary stove. Another method, and much the best, is to introduce the Bunsen flame into the back of an ordinary portable grate. The grate is filled with fragments of fire-brick, which become bright red in the gas-flame, and radiate as much heat as glowing anthracite, which, in fact, they much resemble.

A novel application of petroleum to the production of motive power has been made successful in Hock's petroleum motor, in which vapor of petroleum is exploded behind the piston of an engine and the expansive force made available as a motor. It claims to possess the following advantages over other similar engines:

1. Perfect safety; neither incompetence nor malice can produce a destructive explosion.
2. No particular attention needs to be given it.
3. The facility with which the engine can be started and stopped, no complex preparations being necessary.
4. Its almost noiseless operation. (*b*)

At Mosul, Persia, in the valley of the Euphrates, the crude petroleum and maltha from the springs of Hit is used for burning lime, and proves an invaluable fuel in a country nearly destitute of wood.

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a *New York Herald*, January 6, 1881; *Ibid.*, June 1, 1881.

b *Jour. Frank. Inst.* (3), lxviii, 87.

Chapter V.—THE USES OF PETROLEUM IN MEDICINE.

Section 1.—THE PHYSIOLOGICAL EFFECTS OF PETROLEUM AND ITS PRODUCTS.

Although crude petroleum has been used as a remedial agent from the earliest times, both in the Old World and in the New, I have not met with any recorded attempt at a careful study of its physiological effects. The few notes that I have made in reference to this subject are therefore fragmentary and inconclusive. While in the oil regions I was told several stories relating to the experiences of persons who had breathed natural gas or the vapors of the very volatile fluids that escape from the oil as it flows from the wells. From these several experiences I conclude that the natural gas from the wells intoxicates like laughing gas. Persons leaning over the edge of a well tank experience at first an agreeable sensation, which is followed by unconsciousness. On recovering consciousness the person is very talkative, exceedingly witty, with a vivid imagination. These effects do not disappear for several days, and are described as resembling somewhat those of a prolonged spree. Death results from the prolonged action of the gas. In March, 1880, a man was found dead at the top of a ladder at the man-hole of a tank. He was supposed to have become asphyxiated while watching the flow of oil into the tank, from breathing the gas which was escaping into the air through the man-hole.

Rhigolene, which is the most volatile fluid ever condensed from petroleum, and the lightest liquid known, is an effective anæsthetic agent, and has been used as a substitute for ether in a few instances. Professor Simpson used naphtha (specific gravity not stated) as an anæsthetic during the extraction of necrosed bones. The insensibility was deep and tranquil, and the breathing was less stertorous than when chloroform is used. Its effect on the heart's action, however, was much greater, the pulse becoming more rapid and fluttering. (*a*) Dr. French, of the Liverpool, England, board of health, investigated the subject on a memorial of citizens, and reported that petroleum had an offensive odor, but was not injurious to health. (*b*) Landerer relates a case, but does not say whether the petroleum was crude or refined. It is presumed the material was illuminating oil. A quantity was swallowed, the greater part of which was vomited. It produced a strong, burning sensation in the tongue and throat, both of which became reddened and swollen. The stomach and bowels were also affected with strong symptoms of gastro-enteritis. Both the urine and the sweat smelled strongly of the oil for several days, and the odor was especially strong under the armpits. The patient became very weak, but recovered.

In 1864 M. E. Georges published a memoir upon the physiological effects of petroleum ether, of which the following is a summary:

1. The essence of petroleum acts in a peculiar manner upon the creative faculties (sens génesique), and also under peculiar circumstances upon the temperament.
2. It occasions violent headache with nervous persons.
3. That action appears to be due to a peculiar principle, which may be separated from it, and which acts principally upon the brain and upon the heart.
4. The ether of petroleum can be employed with advantage to produce cold upon the exterior in operations, because it does not produce pain upon the parts where the blood flows. (*c*) The term petroleum ether evidently designates a substance similar to rhigolene.

The neutral paraffine oils and paraffine itself appear to be without action upon the human system. The extensive use of paraffine for chewing-gum shows it to be without deleterious effects.

Petroleum is generally destructive of animal life, and particularly of insect life. Hildebrant, an African traveler, advises smearing the face and hands with petroleum to protect them from mosquitoes. He also advises the use of petroleum upon horses and cattle as a protection against the deadly Dondorobo gad-fly. By its use natural history collections are also preserved from the invasion of moths and ants in the tropics. (*d*) Petroleum has been used in France to destroy insects on plants and walls, also on dogs. In the latter case it is applied either before or with soap. An agriculturist of Aube is reported to have said that rats and mice left his cellar when petroleum was stored there, and slugs left a garden that had been watered with the rinsings of petroleum casks. Its use has been recommended upon plants to kill lice, and also to kill mange and scab on dogs and sheep, for which purpose 10 parts of benzine, 5 parts of soap, and 85 parts of water are recommended. It must be used with great caution upon animals. Those who have used it recommend that it be diluted with benzine. The use of crude petroleum and maltha for ridding vines of parasites has already been mentioned, the product of the Albanian springs having been sent to Smyrna and the Levant for that purpose. Moths are destroyed in furniture and garments by immersing them in baths of benzine. One great obstacle, however, to the frequent use of petroleum products is their disagreeable odor, which to many people is particularly offensive.

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a *An. Sci. Dis.*, 1850. *b* *Ibid.*, 1864. *c* *Ann. du Genie Civil*, 1864, p. 525. *d* *Nature*, xviii, 373.

SECTION 2.—PETROLEUM AND ITS PRODUCTS AS THERAPEUTICS.

Crude petroleum has been used as a remedial agent in both external and internal administration. Its use as a liniment dates from a very remote antiquity. In 1839 M. Fournel addressed a letter to the French Academy, in which he discussed the employment of petroleum by the ancients in the treatment of itch. (a) He says:

> Pliny (Nat. Hist., Book XXXV, chap. 15), speaking of the petroleum of Agrigentum, that was called Sicilian oil, says: "They make use of it for lamps instead of oil; also for the scab in draught cattle." Before him Vitruvius (Ten Books of Architecture, Book VIII, chap. 3) had mentioned the custom among the Africans of plunging their beasts into the waters of a bituminous spring near Carthage; and after him Solinus (Poly. Hist., chap. II), speaking still of the springs of Agrigentum, says: "It [the oil] is used as a medical ointment in the diseases of draught cattle."

All the authors of the fifteenth, sixteenth, and seventeenth centuries have indicated the same remedy, notably among them François Arioste, who cured men and animals afflicted with itch with the petroleum which he had discovered in 1460 on Mount Libio, in the duchy of Modena. Among many others Agricola also may be cited, who said, in the middle of the sixteenth century, "Cattle and beasts of burden, when smeared with it, are healed of the scab." If I pass to petroleum obtained by distillation, I find that in 1721 Eyrinis obtained from the asphaltic stone of the Val-de-Travers, in the canton of Neuchatel, in Switzerland, an oil, of the efficacy of which for the cure of itch he boasted much, affirming that he had cured more than 30 persons by means of it. (*Dissertation upon asphalt or natural cement*, etc., pamphlet in 12mo; Paris, 1721.)

In America crude petroleum has always maintained a high reputation as an external application for rheumatism. The Indians living in the neighborhood of oil-springs used it for that purpose, and the early voyagers learned of them its value. Seneca oil and Barbadoes tar were offered for sale in the United States and Europe many years before petroleum in its present use became an article of commerce. In 1822 the editor of the *American Journal of Science* acknowledges the receipt from James R. Sample, of Barbadoes, of specimens of *Barbadoes green tar*, a petroleum of excellent quality, and indurated bitumen or "munjack", and says:

> The tar is found very useful in preventing lockjaw, when the first symptoms are attended to, by rubbing the spinal bone from end to end and the muscles of the thigh and arms. When taken internally it is also a powerful sudorific. (b)

Again, in 1833, when writing of the petroleum spring at Cuba, New York, Professor Silliman, sr., says the oil was used by people about that place for sprains and rheumatism, rubbed on. (c)

In recent years refined petroleum has borne a valuable reputation as a hair renewer. It is said to promote the growth and luxuriance of human hair and to stimulate the growth of hair on bald scalps to a wonderful degree. Marvellous as are the tales that are circulated by the press, I know of no authentic case, nor have I observed any notices of such cures in reputable scientific journals.

Throughout the oil regions of Pennsylvania petroleum bears a high reputation as an internal remedy in cases of consumption. The oil of the old American well, under the name of American oil, was sold in Pittsburgh for that purpose at the time when Kier was making his first experiment at distilling petroleum. While in the oil regions I met several persons who testified to having witnessed its beneficial effects either upon their own persons or upon those of near relatives. A Mr. S. stated that his brother-in-law was seriously ill with phthisis, when he commenced taking crude petroleum in teaspoonful doses, which he increased in a year to a tablespoonful. His case experienced a marked improvement, and the tubercles were said by the attending physician to have been healed.

During 1879 the French *Bulletin de Therapeutic* contained an article in which it was stated that petroleum had been proved very beneficial in chronic bronchitis, and was thought to be so in phthisis. Administered in teaspoonful doses before each meal, the nausea that was first experienced soon disappeared. For administration it had been put up by a Paris pharmacist in capsules containing 25 centigrams of the oil under the name of "huile de Gabion", after an ancient petroleum spring.

Notwithstanding these well-attested facts concerning the therapeutic action of petroleum, it cannot be said to have a recognized status in American pharmacy.

SECTION 3.—PHARMACEUTICAL PREPARATIONS OF PETROLEUM.

Petroleum has been deodorized and purified for administration by filtering. Within a few years a series of compounds has been prepared for homeopathic practice called myro-petroleum compounds. They are prepared by causing to react upon each other fixed oil of mustard, an alkali, and petroleum. The myronic acid of the oil of mustard forms a salt or soap with the alkali in which the petroleum is dissolved. There are four primary preparations, viz:

1. Myro-petroleum—album.
   Refined petroleum.
   Mustard oil.
   Alkali.

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a C. Rendus, ix, 217. *b Am. Jour. Sci.* (1), v, 406. *c Ibid.* (1), xxiii, 99.

2. Myro-petroleum—nigrum.
   Crude petroleum.
   Mustard oil.
   Alkali.
3. Myro-petroleum soap.
   A mustard-oil soap containing paraffine. The claim is made that paraffine is saponified.
4. Glycero-petroleum.
   Which it is claimed is a petroleum *glycerine.*

The first three preparations are, no doubt, produced as claimed, and their merits as therapeutic agents rest on careful tests, not upon opinion. The claims that are set up, however, for these preparations—that paraffine is saponified and that glycerine is prepared from petroleum—show that the persons making such claims have no clear idea of the chemical constitution of either petroleum or the saponifiable fats. Paraffine was so named from being found destitute of affinity, and acids and alkalies have no more action upon pure paraffine than upon a piece of India rubber, and no substance resembling glycerine has thus far been obtained from petroleum or any of its products. They are all, however, including paraffine, soluble in soaps; hence soaps may be produced containing paraffine or petroleum, but glycerine cannot be obtained from petroleum. About 15 per cent. of paraffine can be incorporated with soap. These soaps are found very valuable in hospital practice for washing malignant ulcers and inflamed mucus surfaces. It is, however, as a material forming the basis of ointments that the preparations of petroleum have obtained their strong hold upon the medical profession. The preparations cosmoline, vaseline, petrolina, etc., which are all essentially the same thing, have now a permanent place in the materia medica.

As early as 1861 C. T. Carney, of Boston, substituted paraffine for wax, spermaceti, and almond oil in cerates, and exhibited specimens at the meeting of the Pharmaceutical Association that year. He remarked:

An ointment made in this way would, in my judgment, be very permanent and keep a long time without becoming rancid or ropy.

White wax in small amount rendered the ointment more tenacious. (*a*) It was not until the discovery and preparation of so-called amorphous paraffine that a material was furnished to pharmaceutists that was destined to supplant the old preparations. I have made no attempt to adjust the conflicting claims of those who manufacture this preparation under different names. I prefer to leave that to the subtle administration of patent law. It is sufficient for my purpose that somebody discovered that when a petroleum residue obtained by evaporating the oil *in vacuo*, or by any other means that will prevent its destructive distillation, is filtered through animal charcoal, an amber-colored, nearly odorless material is obtained of the consistence of paste at ordinary temperatures. One man called it cosmoline, another vaseline, and others have given it other names. Whatever named, amorphous paraffine is rapidly becoming the ointment of the world. It is prepared by the manufacturers either plain or scented with rose or some other perfume for the retail trade, and is also prepared in bulk for the apothecaries.

At the meeting of pharmacists, held in 1880, for the revision of the United States Pharmacopœia, the superior claims of this material over all other preparations as a basis for ointments were acknowledged, and the necessity for its recognition as an officinal preparation of the pharmacopœia was conceded. Some difficulty was experienced in preparing a formula for a substance the origin of which was hidden behind the mysterious veil of conflicting patent rights. On the other hand, the profession was justly cautious in recognizing a name that might designate one thing to-day and another to-morrow. Finally *Unguentum Paraffini* obtained a name and place in the Pharmacopœia. Some difficulty has been experienced in establishing a proper melting point for the preparation. The merits of this question are fully set forth in the following paper, prepared by Dr. Charles Rice, of the Bellevue hospital, New York, and read at the last (1881) meeting of the American Pharmaceutical Association:

"What melting point is most desirable for petroleum ointment?" * * * Our present as well as former pharmacopœias contain two principal classes of unctuous substances intended for external application; one of these of the class of cerates, and the other that of ointments. These have generally been understood to have two entirely different functions, at least in the majority of cases, and for this reason they have been carefully kept apart, although they overlap each other in a few instances. A cerate, as the name already implies, is a "waxy" ointment, that is, an ointment stiffened with wax, for the purpose of raising its melting point. An ointment is intended chiefly for "inunction", and for this reason should possess a melting point but little above that of the temperature of the body. A cerate, on the other hand, is rather intended as a dressing, to be spread on lint, linen, or muslin, and to be applied to the injured surface.

These well-known distinctions furnish the clue to the solution of the question, at least from the standpoint of theory, and also from the standpoint of the physician. The writer has had an opportunity during the past year of learning the views and opinions of a considerable number of practitioners on this subject, and he only regrets that he cannot quote their statements and reports, which were made for another purpose than the drafting of the present paper in full, and with their names attached; but he is at liberty to state that most of them, and among them the foremost dumatologists, pronounce the melting points of several of the commercial petroleum ointments to be altogether too low.

During the heat of summer particularly, and in the warmer sections of our country even in other seasons of the year, an ointment should not have a melting point below about 40° C. or 104° F., and as it is easier to soften an ointment by heat than to stiffen it by cold, it appears preferable to select a uniform melting point for the year round, based on the requirements of the average summer temperature.

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a Am. Jour. Phar. (3), ix, 72.

Petroleum ointment is principally desired by practitioners as a perfectly *bland, neutral,* and *inactive* base for suspending therein various topical remedies. Naturally, this very property of blandness and neutrality will in many cases alone produce curative effects, because it will permit the natural healing process to proceed normally and uninterruptedly, provided the injured part is thoroughly covered so as to exclude the air.

From the opinion of most of the practitioners whose views have been solicited or tendered two petroleum ointments of different melting points are chiefly desirable. One of these, which could take the place of lard or ointment or other low-melting unctuous compound, should have a melting point of 40° C. or 104° F. And the other, which could take the place of cerate or of corresponding compound of higher melting point, should have a temperature of about 46° C. or 115° F.

The preceding would be an answer to the query from the standpoint of the physicians. But there is another feature connected with the query which cannot well be separated from it, though it is not expressed in words. In fact, the question might as well have been formulated thus:

What is the most desirable melting point to be recognized by the next pharmacopœia for petroleum ointment?

While the pharmacist acknowledges the correctness of the distinction between ointment and cerates, and will doubtless agree with the opinion of the physician that there should be both a soft and a firm petroleum ointment, according to the purpose for which it is to be used, he will, on the other hand, most probably deprecate the introduction of more than *one* kind of simple petroleum ointment into the pharmacopœia, because a multiplicity of them will surely result in confusion, both on the part of prescribers and dispensers, and besides, because the likelihood of the pharmacopœial requirements being observed, will diminish in proportion to the number of grades recognized, since it is out of question for the retail pharmacist to prepare the article himself. Hence, from the standpoint of the pharmacist, it will be safest, at least with our present knowledge and experience, to recommend the official recognition of that petroleum ointment only which has the *lowest* melting point declared suitable by competent medical authority. And this melting point is 40° C. or 104° F. Any higher melting point can be easily obtained by incorporating with the petroleum ointment more or less *yellow wax*, and the exact consistence and melting point of the product will, therefore, be more easily within the personal control of the pharmacist than if he were compelled to rely upon the alleged melting point of a manufactured product.

The addition of *yellow wax* to petroleum ointment has long been known to yield a perfectly homogeneous and satisfactory product. Nor does it introduce into the mixture any source of deterioration, at least for any reasonable period of time, since it has been shown that the mixture remains a long while free from all trace of rancidity, particularly if the petroleum ointment itself was sweet and fresh.

It has been said above that pharmacists, as a rule, will probably prefer only *one* officinal petroleum ointment, and this supposition will probably be confirmed should any discussion of this paper take place after being read. But it is also approved by quite a number of physicians with whom the subject has been discussed, and to whom the difficulties attending the recognition of several grades have been pointed out. But, so far as the writer is aware, those who advocate the introduction of only one petroleum ointment, whether pharmacists or physicians, do not deny the correctness of the statement of the other side, that several grades of petroleum ointment of different melting points are very desirable. They only wish to point out that the *official* recognition of more than *one* kind would, by no means, be a guarantee that the other products could even be at all times procured in the market when required, or would be furnished if ordered. And as it is certain that the pharmacist can furnish to the physician equally satisfactory products of *controllable* and *known* melting points, if such are required, by the method above indicated, it is hoped that the two professions will come to the harmonious conclusion to recognize, in the forthcoming new pharmacopœia, only *one* petroleum ointment having a melting point 40° C. or 104° F. (*a*)

The merits of these preparations have met with a very cordial recognition in Europe, and frequent mention is made of them in foreign journals under the names of either cosmoline or vaseline. The following notice from an English journal presents many facts of general interest in relation to the substance and the varied uses to which the apothecary can apply it. It is presented in preference to others for the sole reason that it was convenient of access, and well represents the appreciative consideration which has been extended to "petroleum ointment" on the other side of the Atlantic:

AN ENGLISH VIEW OF VASELINE. (*b*)

By W. H. Symons, F. R. M. S., F. C. S.

Although petroleum in some form or other has been in use for two thousand years (Herodotus, born B. C. 484, is the first writer who distinctly refers to it), petroleum jelly or vaseline has only been known during the last few years, and is said to have been discovered by Mr. R. A. Cheesebrough, of the Cheesebrough Manufacturing Company. I have been unable to find any authentic account of the manufacturing process, but according to the pamphlet which I have on the table, and which most of you have doubtless read, it is the residue from the distillation of petroleum purified by an elaborate system of filtration, known only to the company, or at least so says the pamphlet. This secrecy of its manufacture is one of the greatest drawbacks to its usefulness and official recognition.

Vaseline was the subject of an original paper read by Mr. J. Moss at the meeting of the Pharmaceutical Society, on February 2, 1876. He describes it as a pale yellow, translucent, slightly fluorescent, semi-solid, melting at 37° C. and having a specific gravity of 840 at 54° C. It is insoluble in water, slightly soluble in alcohol, freely so in ether, and miscible in all proportions with fixed and volatile oils. It is not acted upon by hydrochloric acid or solution of potash, and has all the other characteristics of a mixture of paraffines; an ultimate organic analysis made by him gave 97.54 per cent. of hydrocarbons.

Under the microscope, vaseline, in common with most other fats, is found to contain numerous small acicular crystals, doubtless consisting of a paraffine of higher melting point than the mass, but these do not in any way interfere with its usefulness, because of their extreme minuteness and easy fusibility.

Vaseline may be kept indefinitely without becoming rancid; this is its chief characteristic, and together with its indifference to chemicals and its readiness to take any perfume is sufficient to recommend it for pharmaceutical and toilet purposes in place of the fats generally used. (*c*)

If vaseline be considered too thin it may be thickened to any extent with paraffine wax. I have found one to seven a good basis for general use, or one in ten would answer for most purposes; but to obtain anything like smoothness in the mixture it must be thoroughly

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a *Proc. Am. Pharm. Ass.*, 1881; *Oil and Drug News*, September 6, 1881.

b A paper read before the School of Pharmacy Student Association, London.

c One improvement seems to me to be possible, and that is the isolation of single paraffines, of various melting points, one suitable as a basis for liniments, another for ointments, in place of the mixture of paraffines sold as vaseline. (The objections to this multiplicity of preparations have been presented by Dr. Rice.—S. F. P.)

beaten while cooling. Vaseline alone being used for making such ointments as that of ammoniated mercury, or for diluting mercurial or the nitrate of mercury ointments, a partial separation takes place on keeping; but if a mixture of paraffine wax and vaseline be used no such separation occurs.

With regard to the preparations of the pharmacopœia, in which vaseline has been suggested as a substitute for the basis in present use, first and foremost I must mention the nitrate of mercury ointment. Squire states that this can be prepared from white vaseline by substituting it for the lard and oil in the official formula. I tried the experiment on half a pound of white vaseline, using the B. P. quantities of nitric acid and mercury and a temperature rising to 214° F., but it was a decided failure. I could obtain nothing but a mechanical mixture, the vaseline being changed in color from white to pale yellow and the acid solution continually weeping out, and nearly all of it could be separated by pressure. It may be that failure arose from lack of manipulative skill on my part, but I have generally been able to get fair results with the B. P. process. I have on the table a specimen of citrine ointment, prepared from a mixture of white wax and vaseline and about the same quantity of mercury, but rather less nitric acid; this specimen is about eighteen months old, and is as good as when first made. As far as my experience goes, vaseline is not suitable for making citrine ointment of full strength, but it certainly is useful for its dilution. Here is some fresh official ointment, and also some recently diluted with vaseline. I likewise have a specimen which I prepared two years ago; its color is still good. I found that the vaseline had partly separated from it, and in future shall make it with one-eighth paraffine wax.

The next troublesome ointment, I think, is that of red oxide of mercury. I have here a sample of the official ointment, which has been kept for over two years, and is now certainly an unsighly preparation; also some made with prepared lard, quite as bad. Benzoated lard seems to have answered very much better, but still more successful is the mixture of castor oil and beeswax, suggested some years ago in the *Pharmaceutical Journal*. Vaseline, however, will take the palm for more elegant appearance, and it will keep any length of time unaltered.

Compound lead ointment has been spoken of as very liable to change. I have some here made from the official formula which has been kept over a year, and also some made with vaseline eighteen months ago; likewise a sample of zinc ointment. The official ointments, although only a few months old, are quite rancid; but the samples made with vaseline show no alteration after being kept eighteen months.

Mercurial ointment is also very advantageously made with vaseline and wax, instead of with rancid fat, as is usually the case. Under the microscope, samples of both ointments exhibit globules of mercury of about equal size.

Iodine is soluble in about twenty times its weight of vaseline; therefore vaseline is very suitable as a basis for iodine ointment. I am not aware of any action occurring between iodine and the paraffines, although action does take place with chlorine and bromine under favorable circumstances. I prepared some a few days ago of B. P. strength, but without any iodide of potassium.

The crowning success for vaseline is in the preparation of cold cream, and if this were the only compound in which it could be used with advantage its mission would, I think, be fully accomplished. I have made my cold cream for some time with white vaseline, and have found a very marked increase in my sale for that article. I have kept a sample freely exposed to air in a warm place for some months without any alteration, except loss of water. I make it by dissolving ℥ ij. of white wax in 1 pound of white vaseline by heat, adding ʒ iss. of borax dissolved in ℥ ix. of water, and perfume with ʒ ss. of oils, stirring until nearly cold and then pouring into pots.

Vaseline, with or without paraffine wax, is undoubtedly the best basis for pomades, and only requires one-half the quantity of perfume common fats do.

Vaseline has been suggested for internal administration, but it is not the province of the pharmacist to discuss the relative merits or demerits of any therapeutic agent; it behooves him, however, to study the best method of exhibiting it, and to bring it to the notice of the physician.

The Cheesebrough Company prepare vaseline in the form of pastilles, which they say contain 33 per cent. of vaseline, with a like quantity of sugar and gum; these they flavor with wintergreen oil, which is very much appreciated by our cousins across the Atlantic, but not so much so on this side.

Vaseline can be emulsified with the usual agents. The emulsion made with gum acacia is tolerably permanent, also that with yolk of egg. If for external application the vaseline can be mixed with one-eighth its weight of white wax and then emulsified with borax or any alkali. The sample on the table was prepared by triturating ʒ ij. of white vaseline and gr. xv. of white wax with ʒ xiv. of water containing gr. xv. of borax in solution.

I do not look upon vaseline as a nostrum, or I certainly should not have brought it before your notice. It is true we have not yet been let into all of the details of its manufacture, but it may be that such disclosure is not far distant. Because the manufacture of Duncan's chloroform is kept a profound secret among the partners of the firm, has that prevented the medical profession from insisting upon that particular preparation as an anæsthetic? If medical men do not hesitate, when it falls in with the interest of the profession and the public, to recommend a particular preparation of a particular firm to the exclusion of all others, I do not see why chemists should consider it *infra dig.* to recommend and use such an elegant and useful article as vaseline. One trouble looms in the far distance—will the supply of vaseline last as long as the demand for it? Coal may be replaced, and heat and light obtained from electricity by unknown means; but how shall we find a substitute for vaseline, unless, indeed, we be able to make it from its so-called elements? The supply of petroleum does not, however, seem to show any signs of decrease at present. Sources known two thousand years ago still yield bountifully, and if the American supplies prove as permanently productive as those of the Old World we may leave this question for the present. (*a*)

Benzine has been used as a solvent for certain oleo-resins. (*b*) It has been used successfully in the preparation of atropine, santonine, veratrine, delphine, strychnine, brucine, cantharadine, quinine, cinchonine, narcotine, aconitine, and coumarine.

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a London Pharmaceutical Journal, 1881. *b Proc. Am. Pharm. Ass.*, 1873, p. 592.

CHAPTER VI.—MISCELLANEOUS USES OF PETROLEUM AND ITS PRODUCTS.

Petroleum and its products are used for a great variety of purposes that do not fall under the classes previously considered. Commencing with the lightest products, a liquid called cymogene, nearly if not identical with rhigolene, but said to be condensed by pressure, is used in ice-machines with complete success. Gasoline has been proposed as a suitable substance to be used in cleansing raw wool. The following discussion of the use of naphtha (gasoline) for this purpose is introduced here from a circular issued by the Boston Manufacturers' Mutual Fire Insurance Company, with some statements regarding the use of mineral oils for use on wool as the latest information on the subject:

WOOL OILS.

The quality and kind of oil used for preparing wool is a matter of the utmost importance to the underwriter, as it is spontaneous combustion that has caused the record of losses on woolen-mills to be heavier than that on cotton-mills; but in touching upon the subject of wool oils we approach a very "touchy" subject. Many of the methods of treating wool are jealously guarded as trade secrets; the composition of several of the mixtures used on wool has been communicated to us confidentially, and only in order that we may be assured of their safety.

In respect to testimony, we could summon witnesses to prove conclusively that each oil or mixture now used is the very best for its purpose; and conversely that not one of them is really suitable, some difficulty being found either in respect to safety, to the effect on the fiber, or in the removal of every oil used.

All, or nearly all, appear to require a hot solution for their removal, by which the elasticity or luster of the fibers cannot fail to be injured in some degree.

It would appear, according to the evidence and also according to the practice of many of the best manufacturers, that mineral or paraffine oils may be safely and economically used upon wool, either pure or mixed; on other equally competent evidence, that they are utterly unfit to be used and cannot be scoured out, and that nothing but olive, lard, or red oil can be tolerated. The "red oil", so called, is in fact oleic acid, and is subject to impurity if the sulphuric acid used in the process of candle-making (of which "red oil" is a subsidiary product) is not sufficiently removed. When thus impure, we understand it to be peculiarly liable to spontaneous combustion.

The mixed oils, sold under fancy names, of necessity consist of combinations of some of the oils above named, to which the natural yolk or grease of sheep's wool is sometimes added, the latter substance being imported from abroad under the name of "de gras", mostly for the use of curriers.

From the standpoint of the underwriter, the use of mineral oil, mixed to the extent of at least 40 per cent. with animal or olive oil, is to be desired; because in such proportion it abates all danger of spontaneous combustion, and does not in that proportion seriously increase the danger if fire occurs from other causes.

If consideration be given to the work done by the oil, the chief reason why olive, lard, or red oil is preferred, aside from the question of economy, may be that they are a little more viscous than the mineral oils. This may be a point worthy of investigation. If the slight viscosity of fatty oil is desirable, it may be obtained in a mineral oil as well. The substance to be desired is, therefore, one that is not liable to spontaneous combustion; that is not readily ignited by contact with fire; that is readily saponified or reduced to an emulsion, and readily removed from the fiber without the use of any high degree of heat; and that does hold the fibers together in the process of manufacture.

Since none of the oils, greases, or compounds now in use fully meet all these conditions, and since the adverse testimony against them all is stronger than that in favor of any one kind, it follows that both the common practice in scouring all washed or unwashed wool, and the common practice in preparing the wool for carding and spinning, are in some degree bad; that they are not consistent with true economy; that they enhance the difficulties in manufacturing and dyeing, and that if there has been any improvement indicated as being possible by experiments made in a laboratory, from which it is fair to infer that great gain would follow if the theory of the laboratory can be reduced to practice, such experiments deserve the closest attention of all parties in interest.

We therefore beg leave to submit, as the result of our investigation of wool oil, certain propositions. These propositions are submitted only for what they may prove to be worth, and with some hesitation, because none of the officers of the company have ever had any practical experience in the treatment of wool.

Proposition 1. The wool now used in this country will yield 45,000,000 pounds of grease that is now worse than wasted, because it, together with all the alkalies used in the present imperfect method of extracting it, is discharged into ponds and streams, polluting them in a manner most dangerous to health.

2. All this grease can be extracted more perfectly by the use of naphtha than it can be by the use of alkalies, because this grease or yolk does not saponify or yield readily to alkaline treatment until it is in some degree oxidized by age; for which reason the best foreign woolen fabrics are made from wool a year or more old. On the other hand, the newer the clip the more readily the grease is removed by naphtha.

3. The grease and fertilizing material that may be all saved by the naphtha process will more than pay the cost of scouring.

4. This process does not require any heat in the application of the naphtha, and only tepid water for scouring, with a little ammonia in it, it being possible to cleanse a single fleece, by careful manipulation, without disturbing the position of the various portions, thus leaving every fiber in a perfect condition.

5. A portion of the oil thus extracted from the wool itself, after being in some degree refined and mixed with a small portion of mineral oil, makes a viscous emulsion, absolutely free from tendency to spontaneous combustion and in very slight degree inflammable, meeting all the conditions that are required for preparing the wool for carding and spinning.

6. The fiber wool thus cleansed is in much better condition for spinning than when it has been heated and scoured with alkali. Wool and cloth thus treated are in much better condition for the reception of dyes than is possible under any other treatment.

7. This process may be conducted safely in buildings constructed outside mill-yards, at a fair distance away, but not beyond the distance to which the small amount of heat needed may be carried from the main boilers in underground steam-pipes.

In witness of these allegations, we present the report of Mrs. Richards, which was first printed in the *Bulletin of the National Association of Wool Manufacturers*, vol. ix, No. 2.

MRS. RICHARDS' REPORT.

During the progress of the investigation of oil instituted by the Boston Manufacturers' Mutual Fire Insurance Company, for the purpose of abating the danger of fire from spontaneous combustion and other causes, it became expedient to study the natural oil or grease of sheep's wool, which is now saved to a considerable extent in Europe and imported into this country under the name of "de gras", for the use of curriers and for other purposes.

The results of our study of this substance, although not immediately bearing upon the purpose of the inquiry, yet may have an interest to the members of the company, especially those engaged in the manufacture of wool, and are therefore submitted.

The preparation of the raw material is a question of the first importance in any manufacture, and anything which promises to improve the quality of the product, to lessen the labor and cost of preparation, or to lead to the utilization of a hitherto waste product, deserves at least a careful hearing. One of these possibilities seems to be foreshadowed in the wool manufacture.

As is well known, wool, as it is cut from the unwashed sheep, yields from 40 to 75 per cent. of extraneous matter. All this is waste product, and is washed away down our streams to their great damage. Of this large waste, from 12 to 40 per cent., according to the kind of wool, is a grease or oil with valuable properties, and the remainder is largely made up of nitrogenous matters, potash, and phosphates in a very suitable condition to be returned to the soil from whence they were primarily derived. Of course some wools contain sand and mineral dust to the amount of 10 or 20 per cent.

The total amount of washed and unwashed wool used in this country has been estimated at 250,000,000 pounds per year. This will yield approximately 112,000,000 or 115,000,000 pounds of scoured wool, or 45 per cent.; 45,000,000 pounds of grease (18 per cent.); 30,000,000 pounds of fertilizer (12 per cent).

The recovery of a portion of the valuable material has been attempted in France in two ways:

First, by the treatment of the wash-water for the recovery of the grease in a form for gas manufacture, or for the recovery of the potash by the incineration of the evaporated residue, which yields also a very finely divided charcoal, used instead of lampblack. Prussiate of potash has also been manufactured from these residues. By this method, which is an inconvenient one, requiring large tanks and numerous operations, only a portion—about one-third—of the total greasy matter is saved, and none of the nitrogenous matter.

The second method used was the extraction of the grease by means of bisulphide of carbon. The dried wool was then sent to the picking and beating machines before washing, and the wool dust thus obtained was sold for fertilizing purposes. The danger in this process is twofold: the yellowing of the wool by the bisulphide of carbon, and the heat necessary to volatilize the last traces of the solvent (150°–170° F.).

This method, theoretically good, has never been practicable in this country by reason of the cost of bisulphide of carbon. But we have a solvent for grease, in many respects superior to this, which has never yet been applied in this country on a large scale for this purpose, and we have no evidence that, before the present year, any accurate experiments have been made with the best form of this solvent. We have been told of several patent processes for the use of "benzine" for the extraction of the grease; but from the statements as to the results, as well as from a knowledge of the articles sold under the name of "benzine" a few years since, we have no hesitation in saying that the material used was not of proper quality for the purpose or was not carefully applied.

A certain amount of moisture seems necessary to the suppleness of the wool, and any degree of dry heat which takes away this needful moisture renders the wool brittle and harsh. This drying of the fiber is probably the cause of injury in the processes hitherto used.

Our experiments have been made with a quality of naphtha called "gasoline", of about 86°. We have packed the wool in a closed vessel and allowed the naphtha to remain in contact with it for about twenty minutes without any application of heat. The liquid was then drawn off and fresh naphtha run in, the process being repeated three or four times, according to the amount of grease in the wool. "Gasoline" of this quality boils at 90° to 100° F., and air of 50° or 60° F. completely removes it. The naphtha has no affinity for water, and does not, in this cold liquid form, carry away any moisture; very little will be taken out by air at 60° F. before the naphtha is all gone.

In the large way a current of warm air would now be passed through to carry off the absorbed liquid; in our experiments we simply exposed the drained wool to the outdoor air for a few hours. The wool is picked and beaten (the dust being saved), then put into warm water and washed without the aid of any other substance than the soap of potash, which is left on the fiber, untouched, by the naphtha.

The wool thus obtained is very white and soft, and has a "crinkly" appearance.

The objections which have been made to a process of this kind, whether benzine, fusel-oil, or bisulphide of carbon is used, are:

1. That the grease is too completely removed, part being needed to work the fiber.
2. That the grease is also removed from the inner tube of the fiber.
3. That the potash is left in a caustic condition, and hence certain to injure the wool.

In regard to the first objection, Grothe, (*a*) the great German authority, says that the office of the natural grease is so distinct from that of the oil added to facilitate manufacture that this cannot be held valid. The natural grease envelops the fiber as it comes from the hair sack in the skin, making a somewhat stiff coating over it, and only after the removal of this is the wool in the best condition for completely good carding, and also for fulling.

The second objection, that the grease is removed from the tube of the fiber, seems to be founded on earlier ideas. Grothe does not mention this as an objection, and, in the description of the hair, (*b*) says: "In the axis of the hair-shaft is found the pith. This pith is not evident in all wools. In some sorts, viz, Vicuna, it is much developed. The pith-cells contain either liquid or air."

Kölliker (*c*) says that the pith is wanting in colored head-hairs and in most wools: "On treating white hair with caustic soda we get the pith-cells, which do not contain, as was formerly supposed, fat or pigment, but air-bubbles."

It has been stated that washed wool after a time becomes greasy, and it has been supposed that the additional grease came from the pith of the fiber. It is suggested that, as soap can never be entirely washed out of any material, this grease may be derived from the soap used in washing, which is partially decomposed by the cold rinsing-water.

The third objection, that the naphtha or other solvent takes the grease away from the potash on the wool, and thus allows the latter to attack the fiber, seems also derived from a former idea of the nature of the substances under consideration—an idea which is not correct, but which still prevails. The following quotation from an address made in 1872 to a wool manufacturers' association seems to give the prevalent opinion: "In its natural state, as taken from the sheep's back, the whole fleece is filled with a yellowish matter, called by novices grease, but known among dealers as yolk. It is not grease, but a partial soap, being largely composed of alkali, and becoming, if suffered to lie until the volatile oil has dried out, almost a pure soap of itself; hence, as all manufacturers know, old wool scours by ordinary processes much easier than new wool just shorn."

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a Grothe, Wolle, i, 70. Berlin, 1876. *b* *Ibid.*, i, 18. *c* Kölliker, Gewebelehre.

Hartmann, in 1868, showed that this "yolk" is a true grease, containing cholesterine in place of glycerine. (*a*)

Schultze, (*b*) of Zurich, in 1873 and 1874, carried on the research on certain kinds of wool, and it is to his investigation and that of his associates that we owe nearly all of our present knowledge of the composition of the "Wollfett", or grease. He has not only proved the presence of cholesterine, but of isocholesterine and another analogous alcohol. We now know that these substances are in the place of glycerine; hence the far more difficult saponification of this grease than of lard and tallow, which are compounds of glycerine with the fatty acids. Also, the indications are that the wool-fat in the different races of sheep is composed of varying quantities of these cholesterines.

The presence of cholesterine in wool-fat is a very curious fact. Hitherto cholesterine proper has been known chiefly as a product of excretion from the brain, eliminated by the liver; hence its presence in bile. Gautier (*c*) says: "Cholesterine is to the brain what urea is to the blood and other organs."

Why we should find this same substance on the wool of sheep is an unexplained mystery.

The grease is dissolved out by naphtha in the same condition as it is in the wool; a potash soap remains behind untouched.

The proof that the potash is not left caustic is that the concentrated wash-water shows but a very faint alkaline reaction. Only on subjecting it to a high temperature does the reaction become strongly alkaline, showing that a decomposition has taken place.

It may be supposed that because carbonate of potash is made from wool-washings, therefore it exists as such in the wool. It is also obtained from wood ashes, but in neither case does it exist as carbonate before incineration.

The advantages claimed for the naphtha process are the more perfect cleansing of the wool, the better condition of the fiber for taking dyes, etc., the ready recovery of the waste products, hence a prevention of further pollution of streams from wool-washing establishments.

The disadvantage allowed is the inflammable character of the naphtha, rendering a separate building necessary. This is not an insurmountable obstacle, as the use of the substance for several industries has been perfectly successful.

The ultimate cost of the process will depend largely upon the value of the recovered products. This subject has as yet only been touched upon, but we have ascertained that the recovered oil is "equal to the best" for currying leather. It is not liable to spontaneous combustion.

The accompanying table will show the great variation in the wools already tested, the small amount of potash to be obtained, and the necessity of a large number of tests:

	Weight taken in grams.	Per cent. taken out by naphtha.	Per cent. lost on picking.	Per cent. lost on washing in warm water.	Total per cent. lost in cleaning.	Yield of clean wool, per cent.	Carbonate of potash in crude wool.	Per cent. of organic matter, dust picking.	Ash of the grease in per cent. of the grease.	COMPOSITION OF THE RESIDUE FROM EVAPORATING THE WASH-WATER.				
										Per cent. of carbonate of potash.	Iron oxide and phosphate of lime.	Lime carbonate and magnesium carbonate.	Sand, etc.	Total volatile organic matter.
No. 1. Victoria. Not liable to moths...	70	21.43	2.0	21.57	45.0	55.0	3.3	....	0.38	15.4	3.6	(*)	25.8	55.2
No. 2. Cape of Good Hope, Natal. Full of moths.	70	21.70	22.0	15.10	58.8	41.2	1.1	41.45	1.72	7.3	2.7	Like No. 1....	35.3	54.7
No. 3. Buenos Ayres. Full of moths...	70	13.57	15.3	36.13	65.0	35.0	3.1	....	3.50	10.7	1.5	0.6	34.8	52.4
No. 4. Adelaide. Many moths.........	70	22.86	18.0	19.14	60.0	40.0	1.4	18.00	5.00	7.6	4.3	1.6	40.4	46.1
No. 5. Victoria. Not much injured by moths.	70	18.57	6.7	24.63	49.9	50.1	3.0	....	1.40	11.7	1.3	0.5	39.0	47.5
No. 6. Cape of Good Hope. Liable to moths.	70	13.57	4.5	38.33	56.4	43.6	4.4	....	3.80	11.5	3.3	0.8	36.3	48.1
No. 7. Uruguay. Many moths.........	70	12.87	8.0	39.43	60.3	39.7	2.5	....	3.20	6.5	0.9	{0.3 magnesium / Trace only.}	46.7	45.9
Vermont wool. Very greasy............	71	38.50	....	....	76.7	23.3	....	....	....	....	....	....	....	....
West Virgina wool. Very fine..........	1,088	....	....	21.60	....	....	4.2	....	....	19.5	....	....	....	....
Mixed wool..............................	33,770	25.00	....	....	....	....	....	....	0.80	....	....	....	....	....
Mixed wool..............................	7,400	....	....	9.00	....	....	2.5	....	....	27.3	....	....	....	....

* Very little calcium; trace of magnesium.

Naphtha dissolved the grease of all but Nos. 9 and 10 with the greatest facility. These two samples seemed to be older wool, and to have free cholesterine, which was more difficult of solution.

All the samples of wool noticed in the table, except No. 10, were kindly furnished by Mr. George William Bond, to whom we are under great obligation for his interest and co-operation.

No. 10 was furnished by the agent of the Washington mills.

The table will show the small amount of potash which can be obtained, reckoned as percentage on the raw wool. We were surprised at this result, as we had been led to suppose, from various statements, that there was a larger per cent.

The small quantity of ash left by incinerating the grease shows also that it is not a soap of either lime or potash; a portion of this ash was carbon, which is very difficult to burn entirely when derived from cholesterine. It must be remembered also that this was crude grease, which doubtless mechanically carried down some of the other substances.

ELLEN H. S. RICHARDS.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
Boston, May 5, 1879.

We may also cite, in confirmation of these laboratory experiments, the commercial success of the Adamson process of extracting oil by means of naphtha from bone, dead meat, and even in paying quantities from the meat scraps previously treated in the most powerful presses.

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a Inaugural Dissertation. Göttingen, 1868. *b* *Journal für Praktische Chemie.* *c* *Chimie appliquée à la Physiologie*, ii, 216.

This process is also now being applied commercially to linseed and cottonseed, and, in witness of the great affinity of naphtha for oily matter, it may be stated that Mrs. Richards has lately treated some of the hardest and driest cottonseed-cake from the most powerful steam-press now in use for the extraction of the oil; and we find that, after the utmost quantity of oil had been removed by the press, there still remained a quantity equal to 15$\frac{77}{100}$ths per cent. of the weight of the cake.

While the direct result of our investigation of wool oil has therefore only given us the data by which to cause one or two mixtures to be avoided that apparently contained volatile mineral oil, we may yet hope that the final result may be a substantial improvement in the method of scouring wool and woolen fabrics and the saving of a waste substance of great value not only to the woolen manufacturer, but also to the leather-dresser, for whose use large quantities of "de gras" are now imported of a much less pure quality than can be obtained by the naphtha process.

Since naphtha itself is almost a waste product in this country, and is somewhat difficult to obtain in large quantities abroad, owing to the cost and danger attending its transportation, its application to the treatment of wool can be made in this country at much less cost than elsewhere.

The cost of the apparatus would be small, and the waste of material very little, as it can be saved by condensation with very little loss in each treatment.

I am told that the oils that are especially prepared and sold under the name of "wool oils" at the present time are supposed to be in general mixtures of not more than 50 per cent. of mineral oil with either lard, olive, or red oil; and even these mixtures that do not contain more than 50 per cent. of mineral oil are limited in their use to coarse work, it being understood that for fine work the smaller the percentage of mineral oil used the better.

Benzine is equally as useful as benzole for dissolving grease, but it will not dissolve aniline. It is not only used to dissolve grease from cloths, but from animal matter and waste products of any sort from which a refuse fat can be removed. Naphtha of a specific gravity of 62° to 70° B. is used in the manufacture of varnishes, lacquers, and floor-cloths. Rectified anhydrous petroleum spirit (naphtha) of a specific gravity of 0.725 is used to dissolve anhydrous caoutchouc, by which the India-rubber is vulcanized on the addition of chloride of sulphur. (*a*) Naphtha has also been used in air thermometers and for cleaning guns.

Paraffine oil (kerosene) has been recommended to protect seeds from mice, and is said to promote rather than injure vegetation. It has also been successfully used to protect pease from birds, slugs, and caterpillars. Large seeds are soaked in the oil, but it is recommended to sow the ground liberally with sawdust soaked in the oil when smaller seeds are planted. Paraffine oil (lubricating) has been used for saturating gypsum figures and for oiling clocks. Solid paraffine is largely used for stuffing leather, for glazing frescoes and paper, for preserving flowers and wood, and for protecting labels and stoppers of bottles from corrosive liquids.

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a *Le Technologiste*, xxvi, 126, 312; xxx, 308.

CHAPTER VII.—THE INFLUENCE OF PETROLEUM UPON CIVILIZATION.

In an introductory discourse, delivered before the Literary and Philosophical Society of New York, May 4, 1814, De Witt Clinton remarks:

There is a bituminous spring in Allegany county whence the famous Seneca oil is obtained. * * * At Amiano, in Italy, the petroleum of a spring discovered within a few years is also employed to light their cities. * * * It might be of considerable consequence to discover whether the petroleum of our spring might not be used for like beneficial purposes.

It is, however, only during the last twenty years, and through the production of petroleum in the United States, that this substance has exerted a marked influence on civilization; for while petroleum has been produced and used in Burmah, Japan, the Caucasus, Galicia, and Italy for many centuries, it cannot be claimed that its use was more than local, or that such use exerted any extended influence upon the world. Indeed, for the most part it was confined to such rude mechanisms that, as an illuminating agent in those regions, it was much inferior to the materials employed twenty years ago among highly civilized peoples. The earthen lamps of Burmah, the pastils of dried camels' dung used in Persia, and the rude lamps of Galicia were all of them little better than faggots or pitch knots. It is the advent of refined petroleum at comparatively low prices that has practically lengthened the duration of human life and has added vastly to the social enjoyment of mankind, not only among highly civilized peoples, but among the semi-civilized and barbarous nations; in fact, wherever the white wings of commerce can transport it there it has gone, and, more, its light has penetrated even the solitudes of the eastern deserts and the forests of both hemispheres.

Speaking of the rise and progress of the trade in petroleum, Mr. E. W. Binney remarks that it is "the most remarkable rise and progress in a trade in modern times. In 1861 the exports from the United States were 1,194,682 gallons; in 1869 it was 99,148,947 gallons". (*a*)

In considering this influence it may be regarded either as of the past or of the future. Dr. Draper, of New York, writing of the influence of petroleum in America, said, in 1864:

The effect that this illuminating agent has produced throughout the country is very striking. It has entirely displaced all other means of lighting except gas, and is used even in cities by many who desire an absolutely steady light. The great desideratum is a perfect chimneyless burner. The petroleum requires a large amount of air for complete combustion of its carbon, and by no other means than a tube 6 or 8 inches long has the supply been rendered sufficient. Although by the substituting of mica for glass the difficulty of breakage has to a certain extent been overcome, there is still great room for improvement. Kerosene has, in one sense, increased the length of life among the agricultural population. Those who, on account of the dearness or inefficiency of whale oil, were accustomed to go to bed soon after sunset and spend almost half their time in sleep, now occupy a portion of the night in reading and other amusements; and this is more particularly true of the winter season. (*b*)

Notwithstanding the desirability of a chimneyless burner which was thus early felt and clearly stated, that want is yet to be supplied, as all attempts to supply such a burner have thus far been only partially successful. In eastern countries, where the compensation of labor is so small, the cost of chimneys, enhanced by long transportation and breakage, is said to seriously interfere with the extended use of kerosene among the poorer classes. Yet the use of refined petroleum in the East has steadily increased, until petroleum is no longer produced in Japan, and the production has little energy in Burmah.

In 1869 M. Félix Foucou published an article in the *Revue des Deux Mondes* that is especially interesting in this connection. He says:

In the domain of the useful arts each age reveals characteristic tendencies. In the last century mankind had need to clothe itself cheaply. It was this that made the fortune of Arkwright and the machine spinners, the sudden prosperity of Manchester and the continental cities which imported the new method of labor. The nineteenth century has wished for light, both in the birch-bark wigwam of the Indian and in the mud cabin of the poor Ruthenian of Galicia. The introduction of the most modest lamp gives activity to family life in prolonging the evening's labors. France has largely contributed to this result. The invention of Argand, which was the first progressive step in advance of the smoky candle-wick of ancient times, arose painfully at the eve of the French revolution; the Carcel lamp and gas are of yesterday. A crowd of obscure inventors have, with unremitting labor, perfected the mechanism of lamps in order to escape the costly necessity of burning vegetable oils. These experiments, many of which were undertaken under the monarchy, prepared the way for the success of petroleum; unfortunately they came at a moment when it was premature to dream that illumination by mineral oil should become universal. The material was at first wanting; chemistry had not furnished a method of extracting those precious substances from the schists with which they were found associated at many points; and science had not yet shown the part that liquid petroleum was destined to play, of which a great many springs were then known. It is to the Americans that the merit belongs of having given this last right of citizenship among the industries. The native talent that led them to regard the useful aspect of everything, above all the feverish but patient activity, seconded so well by a happy temperament, has served them marvelously on this occasion. The French chemist Selligue gave them the first experiments in the basin of Autun, about the year 1832, by distilling on an industrial scale the schists that abound in that part of France. Mr. James Young, of Glasgow, perfected the process, and established in 1847, in Derbyshire, a vast manufactory for treating the English minerals, incomparably richer than those of France, and known under the names of bog-head and cannel coal. In a few years this establishment took on an extraordinary development, and yielded its

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a Proc. Lit. and Phil. Soc. of Manchester, viii, 135.

b Chem. News, x, 204.

projectors several hundred thousand francs of revenue. The prospect of such profits so soon realized placed this manufacture in a reputable position. It extended to the United States in 1854, where it was employed upon the Scotch bog-head as well as several other indigenous schists. In 1860 there were in North America 64 manufactories of schist oil. The discovery of abundant reservoirs of petroleum suddenly arrested this growing industry, ruined a large number of manufactories, and led their projectors to change them into refineries of petroleum, that substance being much richer in illuminating material than bog-head or cannel coal. (*a*)

This graphic statement of the manner in which the requirements of the age have been met, and how fully they have been met, is well supplemented and illustrated by chart No. III, page 148, in connection with the statistical statement on page 149 *et seq.* The statement shows that in twenty-two years preceding December 31, 1880, there had been produced 156,890,331 barrels of petroleum, of which amount about 16,000,000 barrels were stored above ground, leaving, in round numbers, 140,000,000 from the Pennsylvania oil regions alone for consumption during twenty-two years, an average of 6,363,636 barrels per year. But the production increased from 500,000 barrels in 1860 to 26,032,421 barrels in 1880. The stocks held in the producing regions did not accumulate in excess of the demand until 1875, when they amounted to 4,250,000 barrels; but the demands of the next two years reduced those stocks, and the price advanced to above $2 50 per barrel. Since February, 1878, stocks in the producing region have constantly accumulated, with a constantly increasing demand, and a tendency, as might be expected, to lower prices. The accumulated stocks, January 1, 1882, had reached nearly 30,000,000 barrels.

The total value of the yearly production, as shown by this statement, has been subject to great fluctuations. For instance, the 4,215,000 barrels produced in 1869 were worth $23,730,450, while the 10,809,852 barrels produced in 1874 were worth only $12,647,526. The most valuable production of any year was that of 1877, when 13,135,771 barrels brought $31,788,565, while the 26,032,421 barrels of 1880 brought only $24,600,637. From these figures it is readily perceived that up to the present time the demands of this century for light have been more than satisfied, and that while new uses and applications for petroleum and its products are being constantly discovered the increasing demand has been more than met by an increasing production.

Looking toward the past, it may be said that petroleum has become the light of the world. It is fast displacing vegetable and animal oils as a lubricator on all classes of bearings, from railroad axles to mule spindles. It is also displacing animal and vegetable oils where such oils are liable to spontaneous combustion; it is becoming one of the most largely used materials for fuel in stoves, both for cooking and for heating purposes; it is very successfully used for steam purposes where other fuel is scarce and petroleum is plenty; it is found to be available in the metallurgy of iron, and is likely to be in demand for the production of pure iron for special purposes; its merits have been long recognized in medicine, and it is rapidly becoming a necessity to the apothecary in the form of petroleum ointment; in fact, petroleum has become one of the indispensable needs of civilized man, and ministers to his wants in such a multitude of forms and under such a multitude of circumstances that it may be safely said that it ameliorates the conditions of his struggle with external nature, adds comfort to health, and soothes in sickness, prolonging his active life by extending the day into the domain of night over all that portion of the earth's surface accessible to commerce.

Looking toward the future, what assurance have we that these varied wants, the wonderful creation of twenty-four years, will be satisfied? In answering this inquiry I wish to emphasize the futility of prophecy and the abundance of the present supply. All through the census year, when each successive month brought an addition to the production without precedent, the entire literature representing the oil interest was each month prophesying that the end was being reached, the Bradford field was outlined, the production next month would surely show a decline, the yield of wells was rapidly running down, and so on. As an illustration I quote from Mr. J. C. Welch's *Views of Future Production* for June, 1879:

Reality has been constantly outrunning estimates on the Bradford production. The subject of the amount of production has been somewhat abandoned recently, in the light of the supply being so greatly in excess of any immediate demand, or of any probable demand in a reasonable time in the future. The May production from the wells will be exceeded, no doubt, by the production of some of the summer months. I think a shut-down movement, on account of depleted bank accounts, lack of credit, and a cash system inaugurated by the well-supply dealers of the Bradford district, will be a very important check on the starting of new wells, and the Bradford production probably is about at its height.

He estimated the total daily production for this month at 58,700 barrels. In his *Views of Future Production* for January, 1880, he says:

While the present situation regarding production is bad, great hopes are that in six months the production will necessarily show a very important falling off.

He estimated the total daily production for this month at more than 65,000 barrels. In his report for June, 1880, he says:

The next point is for the production to show an appreciable falling off. This point has not arrived yet, although producers, on account of the falling off of wells throughout the district, expect it will do so pretty soon.

Total daily production for this month, 80,804 barrels. January, 1881, he says:

Public opinion is very greatly in accord with the following extract from a letter of a producer to me: "In some districts the United lines are cleaning out the tanks. Do you get your statements on stocks at wells from the same parties as the *Era* and *Derrick* get

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a Revue des Deux Mondes, April, 1869.

theirs? I sometimes think they back up oil purposely on those who furnish reports. I have interviewed a large number of producers from all sections of the field, and all make the same statement, namely, our production is falling off. I cannot understand, in view of the facts, how there can be an increase in the production, and, in plain words, don't believe it."

Total daily production for this month, 70,427 barrels. In June, 1881, he says:

The sanguine hopes for an important decrease in the production have been postponed for some months at least. Bradford is expected to decline rapidly at some time, and it was confidently hoped the time was near at hand; but the figures on the May production have been disappointing, and any marked decrease in the production is still a matter of the future.

Total daily production for this month, 81,455 barrels. January, 1882, he says:

For the time being the increase at Allegheny equals the loss at Bradford, but this relation is likely to change soon, and not only Bradford will decline, but Allegheny will accelerate the decline by declining itself.

Total daily average production for—

	Barrels.
October, 1881	81,110
November, 1881	80,985
December, 1881	81,462

The following paragraphs were written by an intelligent oil producer of large experience, and express the opinion of conservative operators at the date of their publication, August, 1881:

In the twenty-one years that oil mining has been the chief industry of northwestern Pennsylvania there have been discovered, besides numerous minor deposits, three great basins of petroleum, known among oil men as the Venango, the Butler, and the Bradford districts. The first centers on Oil creek, Venango county; the second on Beaver creek, Butler county; and the third covers an area of about 60,000 acres in the northeastern corner of McKean county, and extends a short distance into the state of New York. The first two named are so far exhausted that a majority of the wells have been abandoned, while those that are still pumped have fallen off until they average less than two barrels each per day. The Bradford district in extent of area and volume of oil exceeds the other two combined. It was discovered in 1875, but it was not until two years later, when its rich character became apparent, that it began to attract the oil men from all other fields. Since then it has been the scene of greatest activity, the magnitude of operations exceeding anything ever known in the business.

In the autumn of 1880, after four years' continuous drilling within and around the Bradford district, the boundaries of this great reservoir were accurately defined; more than 9,000 wells had then been drilled there and were producing oil. These lines being fixed, the producers began to retrace their steps, and to select within these limits such locations as seemed desirable among their old wells and to drill what is technically called the "second crop" of wells. This was the first manifest proof of the limitation of the Bradford district and of its approaching final exhaustion.

The percentage of successful ventures in Bradford surpassed all former experience. Of the whole number of wells drilled in exploring and defining this district about 5 per cent. only were dry or failed to produce oil in paying quantity. In Venango and Butler the average of failure was much larger, and if we except the years when these districts were in their prime, and take those intervening periods in oil mining when the producer had to depend upon the discovery of such minor deposits as lay outside of the great basins, and yet within the oil region proper, it will be found that half of the wells then drilled were failures.

* * * * * * * *

The distinctive features which have marked the development of the Bradford district, and which have given to the Bradford producer advantages over all his predecessors, are: first, the insignificant risk to be taken in drilling; second, the durability of the wells; and third, the expense saved of pumping the wells, which have until recently yielded their oil by flowing. To these natural advantages may be added cheaper machinery and cheaper labor. He has also gained facility by enlarged experience and by his improvements in well machinery. His greatest advantages have no doubt been in the long life of his wells and in the fact that they have been flowing wells; but these conditions have changed. Half of the wells in the Bradford district are now pumped, and the average product per well has fallen to six barrels per day. It is estimated that before the close of the year nearly every well in Bradford must be pumped. They are now passing rapidly from flowing to pumping wells.

The longevity of these wells is accounted for by the thickness of the sand-rock, the natural receptacle of deposit for the oil, which is never found in the Pennsylvania oil region except in this rock. The Bradford rock averages from 50 to 60 feet in thickness, while the Venango and Butler sand-rocks are from 20 to 40 feet. The volume of oil found in any deposit is determined by the extent and porousness of the sand-rock. In one of the minor districts, viz, Triumph, Warren county, the sand-rock was found to be 120 feet thick, and the wells there lasted the longest of any that have been struck; but the area of this deposit was limited to about 1 mile square.

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We have seen that the extent of the Bradford basin was ascertained last autumn. Its margin had been previously defined at many points, but it was not until then that the limits of the whole district became known. We can now see that the greater magnitude of this oil-field will not save it from the fate of the fields that preceded it. The same evidences which marked their decline have already appeared here, and we need not doubt that the same results will follow. The 9,000 wells of last autumn have now increased to over 10,000, and a total of 55,000,000 barrels of petroleum has been drawn from them. It is therefore not to be wondered at that the great reservoir begins to show symptoms of exhaustion. True, these symptoms have only passed the premonitory stage, yet they are as real and significant to the oil-producer as his figures of production. They are to him the "handwriting on the wall", for he knows well how insidiously the same symptoms developed in other districts, and with what accelerating speed the decline went on month by month, as his tables of production showed.

Ordinarily these monthly tables of production are a sufficient guide in forming a judgment of the field; but the condition of the Bradford business for many months has been such as to preclude the possibility of accuracy in them. The product of the district rose so rapidly last year above the receiving capacity of the pipe-lines that much of the oil flowed over on the ground and was lost. This waste continued in varying degrees through the greater part of 1880 and into the second quarter of this year. The extreme cold of last winter, and the aptness to congeal of the Bradford oil (which differs widely in this respect from Venango oil, and in a less degree from Butler oil), complicated the working of the pipe-lines, while diminishing their capabilities; so that the waste of oil was estimated to rise sometimes as high as 5,000, 10,000, and even 15,000 barrels per day. This led the producer to suppress the flow of his wells as much as possible, and to increase the wooden tankage which he uses for temporary storage at his wells until the oil can be conveyed into the large iron tanks of the pipe-lines. These iron tanks have a capacity of from 20,000 to 30,000 barrels each, the usual size of a wooden tank being 250 barrels—1,200 being the largest.

In making up the monthly tables of production it has been found that the greatest accuracy is attained by computing the "runs" of oil into the pipe-lines during the month and omitting the oil held at the wells. When the business is moving normally these well stocks remain nearly stationary and average about a hundred barrels per well, and this average does not seem to be much affected by the fluctuations of the market. A measurement taken in the Butler district in 1876 to ascertain this average gave 100 barrels per well, and this at a time when there were five pipe-lines competing for the oil, and when the price was $4 per barrel. When we consider that the average product of the wells is now 6 barrels each per day, that 200 barrels is usually the minimum taken by the pipe-line in one "run", and that there are 10,400 wells in the Bradford district, it will be seen that the time required for oil to gather to make up these "runs" necessarily leaves stock at the wells at all times, and that there must be a point below which this stock cannot sink until the number of wells decreases, when it will gradually decline with the decline of the district, until both are exhausted.

* * * * * * * *

The total marketable stocks of the region at the end of June, 1881, may be estimated as follows:

	Barrels.
Stocks in United Pipe lines	20,641,285
Stocks in Tide-water Pipe line	1,924,658
Stocks in the minor pipe lines	76,222
Stocks in iron tanks of individuals	420,930
Stocks at wells	335,095
	23,398,190

In a less degree perhaps than any other industrial product is the supply of crude petroleum governed by the price. There have been periods in the business when prices have ruled high, and yet production has declined because of the oil-man's inability to find new productive fields to work. On the other hand, production has not infrequently continued to rise long after the price has declined below cost. A powerful incentive to overproduction is found in the mobile quality of petroleum and its tendency to shift its location in the sand-rock, its passage from place to place through the channels of this natural receptacle having been the cause of many an energetic struggle along the dividing lines of adjoining tracts for the possession of the treasure beneath. These subterraneous currents set toward the first drill-hole on any given tract of land, and are not readily diverted toward subsequent openings; so that the chances for a larger share of the oil and for a more lasting well favor the first well drilled. The exceptions to the rule are rare, and arise from conditions that will readily suggest themselves, such as a natural center of deposit, or, still more rarely, a crevice in the oil-rock. As an oil district is always divided among numerous ownerships, the stimulus to excessive drilling pervades the whole field, and when the deposit happens to be large is sure to lead to excessive production.

Another cause of overproduction is found in the tenure, the tracts being mostly held by lease, the land-owner receiving a rent or royalty in oil varying from an eighth to a half of the total product; a bonus in money is often added when the chances of success seem favorable. The lease always stipulates the number of wells to be drilled and limits the time of drilling them, and also contains clauses of forfeiture to enforce execution of the work. The producer is thus compelled to drill wells at times when the market price of oil does not warrant the outlay rather than forfeit a lease on which he may have already made valuable investments, or which he believes will subsequently prove valuable.

Still another agent, acting in the same direction, is the discovery at a time when the supply is already sufficient to fill the market demand of a new oil-field, richer than any then being worked. The yield of the larger wells in the new district makes the cost of production less than in the old districts, the price declines, let us say, until the producer in the older district receives for his product barely enough to pay the cost of lifting it to the surface, though the producer in the new district still has a profit in his products; both continue their work and production is further enlarged. The first man is impelled to pump his well to save his property from destruction; the second is prompted by the profit he makes. The first man cannot shut his wells down and wait for an advance in price until the new district is depleted, for, besides the inconvenience which such stoppage entails in any business, he would risk the ruin of his wells by the clogging with paraffine of the oil-ducts in the sand-rock, or by the diversion of the oil into other channels by the suction of other wells. The first would be more apt to occur in a waning district and the second in a fresh district, but either is likely enough to happen to admonish him against a shut-down.

Since the discovery of Bradford two other districts of minor importance have been opened. One is known as the Wellsville district, and lies north of Bradford, in Allegany and Cattaraugus counties, New York; the other is the Warren district, lying south of Bradford, in Warren and Forest counties, Pennsylvania. The first has been worked for about three years, and yields the heavy oils only, the gravity varying greatly in different wells, being from 36° to 43° B.; the second is two years old, and yields a light-colored oil of 47° to 48° gravity. About two-thirds of the wells drilled in the first district and one-third of those drilled in the second have been failures. The total daily product in the Wellsville district was, at the close of July, 1881, 350 barrels. Neither gives evidence of large capabilities for increasing production, though of the two the Warren is undoubtedly the more promising. Neither can by any known possibility contain what may be termed "a great basin", for the drilling already done is sufficient to establish the character of both fields. These districts are not even pointers to such a deposit, and if they possess any significance in that direction it is rather against than in favor of such a discovery, so that no marks or guide-posts yet exist to point the way to new fields.

In Wellsville a good quality of oil-bearing rock, varying in thickness from 25 to 35 feet, is found in the productive wells, but that it is of a sporadic character is proved by the large percentage of unproductive wells; and this idea is further confirmed by the remarkable variation in the color of the oil obtained, which ranges from the ordinary green to black. Salt water is produced with the oil in all the wells in the Wellsville district, which is another distinguishing feature of heavy-oil districts, the light oils being always found in the sand-rock entirely free from water. Also, the rock here lies at a higher level than the Bradford rock, and therefore belongs to the upper strata, in which the heavy oils are found.

The Warren oil-rock is from 12 to 25 feet thick, and there are two strata about 100 feet apart; but no well has yet found oil in paying quantity in both rocks, where one overlies the other, as occurs in some parts of the district. The drilling here has been so extended as to leave no space sufficient for a new basin of large capacity; and as north of Wellsville the geological formation changes, the metamorphic rock cropping out in the immediate neighborhood, the oil district cannot extend far in that direction, and at all other points it has been thoroughly tested by the drill.

Stimulated by the large prosperity attending the development at Bradford, test drilling advanced in every direction to the extreme limits of what is geologically regarded as the oil region. For a period of nearly three years, ending with 1880, more of this work was done than during the previous seventeen years since oil mining began; but the want of success in finding new oil-fields, and the enhanced cost and diminished price of petroleum, have all contributed to discourage and arrest this pioneer work.

The impression that there are no more great basins like those of Venango, Butler, and Bradford remaining to be discovered is gradually growing into a conviction that Bradford is indeed the last, and that hereafter this region will have to depend entirely upon minor deposits and districts for its supply. This belief is supported both by the practical experience of oil-men and by the observation of geologists. We are satisfied that no one can make a careful survey of the oil region without being impressed by the great amount of test drilling that has been done. This work has been quietly prosecuted in the depths of the forest and other unfrequented places, and is little noticed and little talked about unless oil is found. It is only the successful adventurer who receives public attention; the unsuccessful man is seldom heard of, but the abandoned well, with its dilapidated "rig", everywhere attests his energy.

From the foregoing statement the following deductions may be drawn:

1st. That the Bradford field, from its uniformity and extent, constitutes the true oil center of the whole region, and that it is already declining; that, as all statistics show, the decline of the old wells averages about 150,000 barrels per month; that this decline has hitherto only been overcome by large and continuous drilling; that the field has now reached a condition where the production cannot be maintained by the incoming new wells; that the number of openings in the field has so drawn upon the common reservoir that further drilling is simply subdivision of what is left and will only tend to hasten exhaustion, and that therefore the decline must proceed month by month with increasing rapidity.

2d. That the production to supply hereafter the large demands upon this region (which will amount this year to 19,000,000 or 20,000,000 barrels) must come from minor deposits.

3d. That to supply this production from these minor deposits will be attended with greater uncertainty and a greater degree of cost than heretofore.

4th. That under these circumstances the stock of crude oil in the region will be held more firmly, and that consequently the range of prices must be permanently higher than during the last three years.

Artificial conditions and the influence of speculation may for a time interfere with, but cannot prevent this result; indeed, nothing can prevent it save that of which there is now no sign—the discovery of a new, great basin. (*a*)

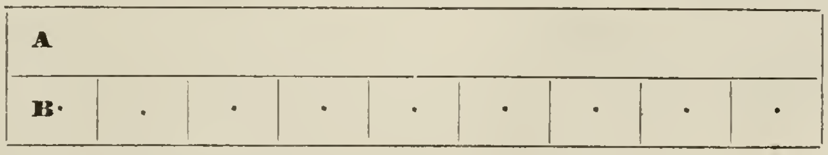
In still further illustration, the following admirable survey of the available resources for future production is quoted from the correspondence of the *Oil and Drug News* for February 28, 1882:

How far off is the date when the production of petroleum will not be in excess of the demand is the great question of the hour to all parties concerned. Daily, monthly, and yearly reports are printed by many parties, a large proportion of which differ one from another. In giving the amount of oil taken from private, wooden, and iron tankage and run into the pipe-lines some reports give the year 1881 credit for the production of the same, when it really was produced in 1879 or 1880. This, of course, would swell the production of 1881 on paper only.

Opperman, a civil engineer and map-maker of this county, and who is good authority, gives the total producing territory in the Bradford field, including Cattaraugus county, New York, at 68,250 acres. February 1, 1882, there were 11,764 wells; and if we estimate 5 acres to the well, 11,764 by 5 gives us 58,820 acres drilled, leaving a balance of 9,430 acres of the lightest territory yet to be drilled, of which from 2,000 to 3,000 can, and probably will, be drilled at present prices, but the balance cannot be operated at less than $1 or $1 25 per barrel.

In November, 1880, there were about 7,000 wells in this field which had been shot with light torpedoes. At this date the large torpedo was found to be more productive, and since this time the greater part of the 7,000 wells have been cleaned out and reshot with the heavy torpedo with good results. (A medium size torpedo nowadays is 60 quarts, which costs, net cash, $290 40.)

Production was further encouraged in 1881 by a great deal of crowding, which I explain as follows:



A wishes to drill one well per month, or wait for higher prices, while B leases his land in small lots. The outcome of this is, a number of wells are drilled along the border of B, which compels A to do the same or lose his oil. This is one of the principal reasons why producers bring their oil to the top of the ground instead of leaving it in the rock at present prices.

The Forest and other large oil companies show by their statements that the cost of production in 1881 was from 30 to 40 cents per barrel more than in 1879 and 1880. This is owing to the pressure of gas and oil upon the rock exhausting, wells ceasing to flow, and pumping resorted to.

The cost per barrel for production in 1879 and 1880 was from 65 to 75 cents, and if the companies are right in their figures the present cost must be considerably above the present market price.

During the six months from July, 1880, to January 1, 1881, the total production of the country was estimated at 90,000 barrels per day, and during much of this time from 3,000 to 6,000 barrels per day was running on the ground in the Bradford field, owing to the inability of the pipe-lines to store and ship the same, and in part owing to the inability of the producers to build private iron and wooden tankage.

During these six months the highest production of the Bradford field was reached, being about 75,000 barrels per day (15,000 being the average production of the other fields). This has gradually declined, until on January 1, 1882, it was about 61,000 barrels per day. This decline includes all drilling of new wells up to that date.

There were more wild cat (or, in other words, prospective) wells put down in 1881 than in all previous years of the oil business, which developed nothing new except the Richburg or Allegany field, in Allegany county, New York. This goes to show that a large territory has been condemned which was counted on as a possible oil-field.

The Allegany field consists of from 7,000 to 8,000 acres, of which about 4,500 is good for 10-barrel wells and upward. The balance from 2- to 10-barrel wells.

On February 1 there were over 600 wells producing from 4,500 acres, and allowing 5 acres to each well, this 4,500 acres will be drilled by April 1, at the present rate of drilling, which is 175 wells per month.

It is estimated that one well to 10 acres is sufficient to drain the land, but where one well is put down to every 5 acres the territory exhausts more rapidly, on the principle of a glass of lemonade exhausting itself sooner when five straws are applied instead of one.

If the Allegheny field is to become a second Bradford, as some seem to say, why is it that the producers have drilled wells so thickly on the 4,500 acres, which is the cream of the territory, and how do they account for the 125 or 130 dry wells immediately surrounding the field? Bradford, in its early development, has scarcely a dry hole in its producing area. In the early days of Bradford torpedoes from

a *Stowell's Petroleum Reporter*, August 23, 1881.

2 to 6 quarts were used, while to-day Allegheny wells are treated to from 40 to 120 quarts, thereby forcing the production to an unnatural large amount for a short time, but the land is being drained correspondingly rapidly.

The following shows the condition of the oil production, etc.:

	Barrels.
Total oil in all pipe-lines, January 1, 1881 (*a*)	16,606,343
Total oil at wells in Bradford field, January, 1881 (*b*)	2,403,500
Total oil in private iron tankage, Bradford field, January 1, 1881 (*c*)	692,750
	19,702,593
Total oil in all pipe-lines, January 1, 1882 (*a*)	25,333,413
Total oil at wells in Bradford and Allegheny fields, January 1, 1882 (*c*)	1,135,848
Total oil at private iron tanks, Bradford and Allegheny fields, January 1, 1882 (*c*)	104,256
	26,573,517
Deduct amount for January 1, 1881	19,702,593
Total net increase of stock in oil regions on January 1, 1882	6,870,924

This amount divided by 365 days gives:

Total net average daily increase in stocks in 1881	18,824
Total net average daily shipments from oil regions in 1881 (*a*)	55,774
Add the daily average increase and shipments for net production	74,598
Add the daily average evaporation and shrinkage (*a*)	2,150
Giving the daily average gross production	76,748
The daily average shipments of 1880 (*a*) were	42,916
The daily average shipments of 1881 (*a*)	55,774
Shows increase in 1881 over 1880 to be per day	12,858

Our export trade has increased nearly every year since 1852. I copy the following from the *American Exporter* for December, 1881:

	Gallons.
Total exports of petroleum and petroleum products for October, 1881	54,244,846
Total exports for same, October, 1880	34,065,254
Increase for October, 1881, over October, 1880	20,179,592
Total for 10 months ending October 31, 1881	422,713,216
Total for 10 months ending October 31, 1880	295,520,798
Increase foreign demand in ten months	127,192,418

The *Oil and Drug News* of January 31, 1882, says:

The total exports of petroleum and petroleum products from the port of New York, in gallons, from January 1 to January 28, 1882, as compared with those of the same period in 1881, are:

	1882.	1881.
Crude, gallons	2,913,442	2,641,430
Refined, gallons	16,556,230	10,035,481
Naphtha, gallons	153,131	541,297
Total	19,622,803	13,218,208
Total increase in foreign demand for the first 28 days of this year, gallons.		6,404,595

Now let us take into consideration the increase in home consumption.

For illuminating purposes it is universally used throughout the country, except where gas exists, and with the wonderful increase in railroads to the far west and south, including all the mining regions, and the increase of population, an unusual increase is sure to follow.

The exact amount of home consumption has never been actually given; it has only been estimated.

In 1880 it was placed at 13,000 barrels per day; in 1881 there were 55,774 barrels (*a*) per day shipped from the oil country, and 40,800 barrels (*b*) per day exported from the United States. The difference between the exports and the shipments from the oil country would show the home consumption to have been 15,000 barrels per day, but there was estimated to have been a large amount of the stocks used, which was stored at the refinery centers and sea-boards, estimated at about 3,000 barrels per day; add this to the 15,000 shows the estimated home consumption for 1881 to have been 18,000 barrels per day, which is an increase over 1880 of 5,000 barrels per day. Owing to the rapid development of the far south and west, and the general prosperity of the country, the home consumption may safely be estimated at 22,000 barrels per day for 1882.

Eight persons out of ten say that Allegheny is at its height, and I have shown where it is probable that the cream of her territory will be drilled by April 1 next, from which time her production will decline. Then consider the number of dry wells which have been drilled in all parts of the country, which shows that the prospects for developing a new oil-field are not very promising.

With Allegheny so near drilled out, the Bradford field declining at from 75,000 to 100,000 barrels per month, and other territory not increasing, is it not natural to predict that the quantities of production and demand must soon come together, at which time prices will naturally advance rapidly? Taking into consideration the reshooting of wells in Bradford field in 1881, the finding of the Allegheny field, the extra amount of crowding lines, etc., after all this the total net increase of stocks in oil regions, January 1, 1882, over January 1, 1881, is only 6,870,923 barrels, while the increase in shipments were 12,858 barrels. Add to this the decrease of stocks at refinery centers, 3,000 barrels, gives 15,858 barrels increase demand per day, or 5,757,510 barrels for the year.

a Official. *b Bradford Era.* *c* Producers' report.

The consumptive demand of the world for 1881 was about 21,535,902 barrels, or 59,000 barrels per day, and the demand for 1882 is estimated at, at least, 15 per cent. more (15 per cent. is the average increase the past ten years), which will amount to 24,766,187 barrels for the year, or 67,852 barrels daily average, exclusive of evaporation and shrinkage. The 25,333,413 barrels in pipe-lines seem to lead some people astray.

The above figures show that the entire amount, if drained from the lines, would be only one year's demand, and all know that we could only spare, say, 10,000,000 barrels, as about 15,000,000 is required to carry on the business in the same way as a bank requires capital. Should a few million barrels be taken from the present stock, this, together with the increased consumption, would revolutionize prices.

These illustrations received increased significance when it is understood that within twelve months of the time the first paper was written and immediately following the date of the last the Warren district yielded some of the largest wells on record, and the price of oil tumbled to a still lower figure, instead of being permanently higher.

While it is not probable that the deposits of petroleum within the crust of the earth are being practically increased at the present time, there is reason to believe that the supply is ample for an indefinite period. When prophecy, indulged even by the most sagacious producers of longest experience, proves so futile, I think I am warranted in expressing the opinion that, as regards the future supply of petroleum, the drill alone gives valid testimony. Yet this fact is worthy of the most serious consideration: the production of petroleum as at present conducted is *wasteful in the extreme*. No thoughtful person can escape the conviction that future generations will want what this present generation is destroying to no purpose. "After us the deluge," is written all over the oil region in the destruction of forests and in the waste of the oil itself.

STATISTICS OF THE EXPORTS OF PETROLEUM DURING THE CENSUS YEAR.

The following tables have been prepared for the purpose of showing the relative magnitude of the export trade in petroleum during the census year, the relative amount exported from different ports of the United States during that year, the points to which it was sent, and the relative amount of such export trade in the different manufactured products of petroleum during different years. These tables consist of:

Table I.—Shipments of crude and refined oil out of the producing region to the following points during the census year, by months.

Table II.—Receipts of crude and refined petroleum, etc., at New York, weekly, by routes, during the census year.

Table III.—Exports of petroleum and petroleum products from New York to foreign ports for 1878, 1879, 1880, and the census year; also from Philadelphia for the same time.

Table IV.—The charters reported for crude and refined petroleum, naphtha, and residuum, from New York, Philadelphia, Boston, Baltimore, Richmond, and Portland, to the different ports of the world, exclusive of North America, during the census year.

Table V.—Petroleum and its products exported from the United States during the years ending June 30, 1879 and 1880.

Table VI.—Exports of petroleum and petroleum products from all United States ports to all foreign countries, and the declared value thereof, from 1873 to 1880, inclusive, and the census year, by months.

Table VII.—Quantity of petroleum produced, and the quantity and value of petroleum products exported from the United States during each fiscal year from 1864 to 1880, inclusive.

Table VIII.—New York petroleum market, average prices per year.

Table IX.—Imports of refined petroleum at five principal ports of the United Kingdom, with stocks at the same ports, January 1, 1874, to 1881, inclusive.

Table X.—Imports of petroleum at the undermentioned European ports for seven years ended December 31, from 1874 to 1880, inclusive.

Table XI.—The various products of crude oil, including petroleum, crude oil, refuse oil, and grease, and all products of naphtha exported from Baku, from 1832 to 1879, in poods of 36 pounds each.

Table XII.—Imports of American petroleum (refined) into Japan, from the time of the first importation, in 1872, to the end of 1880.

An inspection of these tables shows a steady increase in the quantity of petroleum and petroleum products exported to the end of 1879; 1880 showed a slight decrease. The months constituting the census year—from June 1, 1879, to May 31, 1880—exhibit an unparalleled activity in almost every item where the statistics were to be found in such form that the months of the census year could be separated from the totals for 1879 and 1880.

Table I shows that the shipments of refined oil from the producing region to New York declined during 1880 more than 1,100,000 barrels, or about 68 per cent. This decline took place mainly after the close of the census year, as the shipments for that year amounted to nearly 85 per cent. of those for 1879. Shipments to both Philadelphia and Baltimore of refined oil were merely nominal both during the census year and during 1880, while there were no shipments in 1879 to either of these points.

The shipments of refined oil to Boston and local points were not materially changed in the aggregate for the two years, but the amount shipped during the census year exceeded that moved during either 1879 or 1880.

The shipments of crude oil out of the producing region to New York, Philadelphia, Cleveland, the Ohio river, and local points show a marked increase in 1880 over 1879, while the shipments to Baltimore, Boston, and Pittsburgh show a considerable decline during the same time; yet to all of the points mentioned above, excepting

the local points, the shipments during the census year were larger than during either of the years of which it forms a part. The total shipments of crude oil out of the producing regions in 1879 to the points above mentioned was 15,987,370 barrels; in 1880, 15,675,492 barrels; and during the census year, 17,769,656 barrels, an amount 11 per cent. greater than the average for the two years.

Table II shows in the totals the same steady increase in the movement of crude oil to New York, and an equally steady decline in the movement of refined oil to the same point. During 1877, 103,662,216 gallons of refined oil entered New York, and by 1880 the receipts had fallen to 42,847,577 gallons, although the amount received during the census year was nearly equal to that received during 1879. During 1877 the receipts of crude oil at New York were 179,214,244 gallons, an amount which was increased to 256,878,660 gallons during 1880, and to 285,839,983 gallons during the census year. These figures indicate a diversion of the product of the refineries located in the interior cities from the export trade and an increase in the proportional supply of that trade by New York city. Table I also shows a similar increase in the consumption of crude oil for Philadelphia and Cleveland, while Boston, Baltimore, and Pittsburgh exhibit a large decline in receipts of crude oil during 1880. It seems, therefore, fair to assume that the manufacture of oils for export has steadily increased in New York, Philadelphia, and Cleveland, and has declined in Baltimore, Boston, and Pittsburgh, notwithstanding the movement of refined oil toward New York has steadily declined, and has been merely nominal toward Philadelphia and Baltimore, while the amount received at Boston has remained practically unchanged.

Table III shows the relative amount of petroleum and petroleum products exported from New York and Philadelphia to different countries during 1878, 1879, 1880, and the census year. The special activity of the export trade during the census year is illustrated by this table, not only in the totals, but also in the items.

Table IV exhibits the destination of the petroleum and petroleum products sent from the country during the census year, the manner in which it was packed, and the kind of material sent to different ports and countries As this table was compiled from the charters reported, some of which were vessels that arrived or were filled after the census year closed, the amounts do not correspond with those given in other tables, which were compiled from the clearances. This discrepancy does not vitiate the statistics of the table for the purpose given above.

The charters for crude oil were for—

	Barrels.	
France	395,560	
Belgium	85,500	
Spain	61,400	191,600 cases.
Bremen	30,800	
Continental ports	18,500	
Mediterranean ports	7,509	
Ireland	5,000	
Total	604,269	191,600 cases.

The charters for refined petroleum were—

For Europe, including the Mediterranean islands:	
Barrels	5,213,081
Cases	1,366,150
Miscellaneous Mediterranean ports, the Levant, Asia Minor, and Syria:	
Barrels	50,800
Cases	874,000
Africa and Mauritius:	
Barrels	2,000
Cases	380,000
Asia, Australia, and the East Indies:	
Cases	6,003,800
South America:	
Cases	17,000

The charters for naphtha were for—

England:	
Barrels	106,050
France:	
Barrels	87,650
Cases	4,900
Belgium:	
Barrels	23,200
Cases	10,000
Sweden:	
Barrels	13,900
Continental ports:	
Barrels	10,300

The charters for residuum were for—

	Barrels.
England	89,900
France	2,000
Antwerp	300

The following-named geographical sections took charters in the census year as given below:

	REFINED.		NAPHTHA.		CRUDE.		RESIDUUM.	
	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.
Great Britain	1,218,150		106,050		5,000		89,900	
Sweden and Norway	77,800		13,900					
Denmark	97,800							
Miscellaneous Baltic ports	361,650							
Russia:								
Baltic	13,950							
Black sea		48,000						
Holland	177,300							
Germany	1,594,256				30,800			
Belgium	552,800	1,000	23,200	10,000	85,500		300	
Continental Europe	706,000		10,300		18,500			
France		7,000	87,650	4,900	395,560		2,000	
Spain:								
Outside	15,400	155,700			61,400	191,600		
Inside	12,300	244,250						
Portugal	32,509	17,000						
Sardinia		12,000						
Sicily		113,000						
Italy	76,700	298,000						
Malta		15,000						
Adriatic ports	7,000	102,000						
Trieste	268,966							
Ionian islands and Greece		73,200						
Turkey in Europe		280,000						
Levant		186,000						
Miscellaneous Mediterranean ports	50,800	602,500			7,509			
Syria and Asia Minor		85,500						
Egypt		230,000						
Algiers	1,000	53,000						
Liberia	1,000	21,000						
Zanzibar		45,000						
South Africa		6,000						
Mauritius		25,000						
British India		1,149,800						
Ceylon		95,000						
Rangoon		151,500						
East Indies		153,000						
Java		2,555,000						
Australia		50,000						
New Zealand		20,000						
Manila		17,000						
China		650,500						
Japan		1,028,000						
Singapore		112,000						
Saigon		22,000						
Buenos Ayres		10,000						
Brazil		7,000						

Commencing at the head of the list, it will be observed that 4,799,706 barrels of refined oil were chartered for Great Britain and the continent of Europe north of France. This amount was all chartered in barrels, with the exception of only 1,000 cases, probably of a special brand, which went to Antwerp. In addition to this vast quantity, amounting to nearly 68.5 per cent. of the total charters of refined oil, there were chartered for the same region 153,450 barrels and 10,000 cases of naphtha, 139,800 barrels of crude oil, and 90,200 barrels of residuum, of which latter material all but 300 barrels were for Liverpool and London, England.

There were chartered for France only 7,000 cases of refined oil, which was for the port of Marseilles, and probably consisted of some special brand. The charters for France, however, included 87,650 barrels and 4,900 cases of naphtha, 395,560 barrels of crude and 2,000 barrels of residuum. France has for many years laid an import duty on refined oils and admitted crude oil free, thus fostering the manufacture of refined oils on her own soil. This fact accounts for the heavy charters of crude oil for French ports.

The charters for Spanish ports embraced both refined and crude oil in barrels and cases. There were chartered for Spain 61,400 barrels and 191,600 cases of crude oil. It will be observed that the charters for the inside ports of Spain include a larger proportion of case oil than the outside. Nearly two-thirds of the oil chartered for Portugal is in barrels. With the exception of 7,509 barrels of crude oil chartered for miscellaneous Mediterranean ports, probably Spanish and French, no crude oil, naphtha, or residuum was chartered east of France or south of

the straits of Gibraltar. All of the refined oil chartered for Austria through Trieste was in barrels, besides which 135,500 barrels were chartered for Italy and various Mediterranean and Adriatic ports in barrels. The remainder of the oil chartered for ports between France and Port Said was all case oil, and amounted to 2,098,200 cases. All of the oil chartered for ports south and east of the Mediterranean sea, with the exception of 1,000 barrels for Las Palmas, Canary islands, was case oil. The trade with eastern Asia, including India, the islands, China, and Japan, in case oil is enormous, the charters amounting to 5,933,800 cases for the census year.

Table V shows the relative amounts of the different products of petroleum sent from the different ports, and also gives the amounts and values of lubricating oils exported. In 1879 New York exported of lubricating oils less than one per cent. of the amount of illuminating oils exported, while Boston sent out of lubricating oils nearly 10 per cent. of the amount of illuminating oils exported. The quantity of lubricating oils exported in 1880 was nearly double that of 1879. The total exports of 1880 were more than 45,000,000 gallons in excess of those of 1879, yet their total value was more than $4,000,000 less for the last-named year.

Table VI shows the quantity and value of petroleum and petroleum products exported from the United States from 1873 to 1880, inclusive. This table shows generally a steady increase in the quantity of the different products exported from year to year, but the value of these different quantities varied greatly. For instance, in 1876, 25,343,271 gallons of crude oil were exported, worth $3,343,763, and in 1880, while the quantity was increased to 35,481,168 gallons, the value was decreased to $2,679,193. In 1877, 309,778,832 gallons of refined oil were exported, worth $51,901,106, while the following year, although the amount was lessened only 882,525 gallons, the value was reduced $12,806,655, and in 1879, while the quantity reached 367,321,255 gallons, the value fell to $32,696,713, and in 1880 was still less. The exports of petroleum and its products were valued in 1877 at $57,497,164, a larger amount than has been realized from the same source in any one year prior to January 1, 1881.

Table VII shows the production and quantity and value of exports for seventeen years ending June 30, 1880; that is, for the last seventeen fiscal years prior to and including the census year. (*a*) The fluctuations in relative quantity and value are exhibited in this table.

As an illustration, in round numbers, the 425,000,000 gallons exported in 1880 brought $500,000 less than the 150,000,000 gallons exported in 1871, and about 65 per cent. of the amount obtained for 309,000,000 gallons in 1877. The exports of the fiscal year 1877 were valued at $61,789,438.

The remaining tables need no explanation.

THE CONSUMPTION OF PETROLEUM AND PETROLEUM PRODUCTS IN THE UNITED STATES.

The amount of petroleum and petroleum products consumed in the United States in any given time is a residual quantity consisting of elements very difficult to estimate with absolute accuracy. An approximate estimate, however, has been repeatedly made by subtracting the exports, reduced to crude equivalent from the production, less the accumulated stocks. This method, never of much value, is becoming more unreliable each year as the increasing demand for mineral oil residues increases the production of reduced petroleum, and, consequently, the proportion of illuminating oil manufactured without cracking, and therefore not representing 75 per cent. of the crude oil. The production of oil out of the ground for the census year has been already estimated at 24,354,064 barrels. Of this amount 315,000 barrels were estimated to have been wasted or burned, leaving 24,039,064 barrels as the available production, of which 5,350,863 barrels were added to the stocks already accumulated. Of the remaining 18,688,201 barrels, 17,417,455 barrels were manufactured in this country and 673,763 barrels were exported, leaving 596,983 barrels for consumption in this country.

Of illuminating oils of all grades there were manufactured 11,002,249 barrels, of which 7,346,516 barrels were exported, leaving 3,655,733 barrels for home consumption, an average of about 10,000 barrels per day.

Of lubricating oils there were manufactured of all kinds and grades 380,739 barrels, of which 103,257 barrels were exported, leaving 277,482 barrels for home consumption. Oils consisting in part of crude petroleum are not included in the above amount.

Of naphthas of all grades, including gasoline, there were manufactured 1,508,049 barrels, of which 368,221 barrels were exported, leaving 1,139,828 barrels, of which 57,843 barrels were used as fuel by the manufacturers of petroleum, leaving 1,081,985 barrels for home consumption.

It is impossible to assign any definite amount as representing the consumption of residuum; 229,173 barrels were sold by the manufacturers and 235,314 barrels were burned by them as fuel. Of the 229,173 barrels, 94,141 were exported, leaving a remainder of 135,032 barrels, nearly the whole of which was used as raw material by the manufacturers of lubricating oils. The term "residuum", as it has been used in this report, is probably not properly applied to the whole of the 94,141 barrels reported as exported; but it is impossible to distinguish in the statistics of exports between the different materials, denominated "tar", "pitch," etc., included under the term "residuum."

I have not met with any notice of the export of paraffine wax, but it is not therefore safe to infer that the 7,889,626 pounds manufactured were all consumed in the United States. One firm manufactured 900,000 pounds of candles. While the manufacture of candles represents the largest use for any one purpose, the great number of uses to which it is now applied in the arts represents an enormous consumption of this substance.

a The census year closed May 31. Practically the last fiscal year is the census year.

The actual consumption of crude petroleum represented by these figures is, after all, only an approximation to a correct result. If the illuminating oils are assumed to represent 75 per cent. of the crude oil, the consumption of crude oil as illuminating oil was 4,874,310 barrels, or 13,354 barrels daily; but in reality the illuminating oil, all grades taken together, does not represent 75 per cent. of the crude oil, and I am inclined to think that 15,000 barrels daily is not far from a correct estimate for the consumption of crude petroleum in the United States during the census year.

TABLE I.—SHIPMENTS OF CRUDE AND REFINED OIL OUT OF THE PRODUCING REGION TO THE FOLLOWING POINTS DURING THE CENSUS YEAR.

[Compiled from the reports of the New York Produce Exchange.]

Month and year.	REFINED REDUCED TO CRUDE.					CRUDE.									
	New York.	Philadelphia.	Baltimore.	Boston.	Local points.	New York.	Philadelphia.	Baltimore.	Boston.	Cleveland.	Pittsburgh.	Ohio river.	Local points.	Fire.	Total.
1879.	*Barrels.*	*Barr'ls.*	*Barr'ls.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barr'ls.*	*Barrels.*
June	210, 488	....	....	37, 830	24, 984	643, 817	29, 151	53, 957	10, 087	114, 810	207, 697	17, 720	18, 773	....	1, 369, 314
July	240, 311	....	....	62, 493	15, 516	465, 824	139, 968	57, 187	23, 203	292, 924	278, 030	20, 336	29, 243	....	1, 625, 035
August	177, 407	....	....	37, 350	25, 806	655, 416	196, 915	57, 337	10, 178	314, 477	284, 563	15, 214	33, 576	....	1, 808, 239
September	135, 043	....	....	26, 977	42, 468	623, 832	169, 062	65, 459	16, 169	296, 116	207, 863	5, 403	38, 728	....	1, 627, 120
October	169, 335	....	....	33, 942	30, 666	502, 400	149, 349	74, 648	10, 352	369, 779	267, 975	5, 932	48, 791	....	1, 663, 169
November	183, 386	....	....	28, 625	55, 245	611, 630	137, 997	56, 778	8, 428	228, 634	193, 770	12, 597	36, 555	....	1, 553, 645
December	91, 114	....	....	55, 085	40, 267	667, 533	221, 743	77, 310	11, 433	242, 415	70, 072	27, 257	28, 356	....	1, 532, 585
1880.															
January	55, 071	90	....	33, 911	49, 098	810, 131	171, 330	78, 017	11, 541	228, 145	152, 330	20, 254	40, 491	....	1, 650, 409
February	24, 382	....	....	18, 050	54, 100	758, 157	179, 145	96, 146	....	156, 041	53, 418	9, 850	42, 862	....	1, 392, 151
March	62, 740	....	....	23, 989	18, 269	984, 808	220, 517	80, 645	9, 489	151. 775	32, 590	7, 400	21, 240	....	1, 613, 462
April	19, 225	....	....	13, 502	21, 079	385, 727	97, 147	12, 816	5, 758	141, 197	65, 619	62, 194	15, 004	....	839, 268
May	2, 001	175	499	18, 940	23, 781	513, 704	61, 503	31, 779	4, 642	102, 358	105, 657	3, 818	26, 402	200, 000	1, 095, 259
Total, census year	1, 370, 503	265	499	390, 694	401, 279	7, 622, 979	1, 773, 827	742, 079	121, 280	2, 638, 671	1, 919, 584	207, 975	380, 021	200, 000	17, 769, 656
Total, 1879	1, 612, 550	....	....	379, 293	333, 446	6, 318, 532	1, 607, 998	677, 273	120, 584	2, 502, 570	1, 901, 649	183, 131	350, 344	....	15, 987, 370
Total, 1880	509, 769	2, 248	7, 322	378, 635	397, 369	6, 461, 465	1, 741, 286	604, 183	99, 819	2, 535, 216	958, 336	206, 577	935, 810	582, 490	15, 420, 525

PERCENTAGE OF DELIVERIES OF CRUDE AND REFINED OIL AT THE ABOVE NAMED POINTS.

Census year	63. 35	0. 01	0. 03	18. 06	18. 55	48. 85	11. 37	4. 75	0. 78	16. 91	12. 30	1. 33	2. 43	1. 28	....
1879	69. 35	....	....	16. 31	14. 34	46. 25	11. 77	4. 96	0. 88	18. 32	13. 92	1. 34	2. 56	....	....
1880	39. 35	0. 17	0. 57	29. 23	30. 68	45. 74	12. 33	4. 28	0. 71	17. 95	6. 78	1. 46	6. 63	4. 12	....

TABLE II.—RECEIPTS OF CRUDE AND REFINED PETROLEUM, ETC., AT NEW YORK, WEEKLY, BY ROUTES, DURING THE CENSUS YEAR.

[Compiled from the reports of the New York Produce Exchange.]

For week ending—	BY ERIE RAILWAY.			BY HUDSON RIVER RAILROAD.		BY PENNSYLVANIA RAILWAY.			CAÑAL.	TOTAL.		
	Crude.	Refined.	Naphtha.	Crude.	Refined.	Crude.	Refined.	Naphtha.	Crude.	Crude.	Refined.	Naphtha.
1879.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
June 5	1, 641, 465	358, 093	....	1, 805, 265	1, 031, 321	2, 619, 193	20, 220	....	567, 730	6, 633, 353	1, 409, 634	....
June 12	1, 366, 695	982, 488	....	1, 862, 235	699, 501	3, 227, 714	....	....	....	6, 456, 644	1, 681, 989	....
June 19	640, 080	378, 256	....	1, 780, 065	1, 273, 512	2, 765, 171	21, 798	....	901, 108	6, 086, 424	1, 673, 566	....
June 26	1, 730, 340	756, 606	....	1, 557, 630	1, 162, 451	2, 558, 377	64, 296	....	250, 914	6, 097, 261	1, 983, 353	....
July 3	1, 513, 080	709, 324	....	1, 223, 370	1, 626, 623	2, 453, 333	144, 572	....	....	5, 189, 783	2, 480, 519	....
July 10	840, 375	818, 223	....	982, 215	1, 268, 483	1, 584, 893	78, 960	....	....	3, 407, 483	2, 165, 666	....
July 17	616, 770	1, 188, 630	....	1, 029, 420	2, 086, 612	2, 379, 670	520, 525	....	48, 005	4, 073, 865	3, 795, 767	....
July 24	539, 955	931, 869	....	1, 407, 960	2, 170, 037	2, 207, 696	849, 901	....	....	4, 155, 611	3, 951, 807	....
July 31	1, 733, 946	1, 127, 248	....	1, 687, 860	1, 646, 316	2, 166, 219	885, 762	....	....	5, 588, 019	3, 659, 326	....
August 7	1, 048, 095	464, 172	....	1, 712, 025	2, 139, 487	2, 278, 433	957, 719	....	....	5, 038, 553	3, 561, 378	....
August 14	1, 126, 575	830, 537	....	2, 379, 240	2, 579, 830	2, 080, 899	1, 617, 082	....	....	5, 586, 714	5, 027, 449	....
August 21	1, 570, 050	952, 925	....	1, 915, 200	1, 428, 236	1, 517, 964	1, 257, 156	....	....	5, 003, 214	3, 638, 317	....
August 28	1, 854, 720	771, 787	....	2, 429, 010	1, 496, 574	2, 161, 847	1, 530, 884	....	....	6, 445, 577	3, 799, 245	....
September 4	2, 090, 880	188, 141	....	2, 343, 555	923, 823	1, 744, 387	1, 210, 391	....	....	6, 178, 822	2, 322, 364	....
September 11	1, 655, 460	110, 732	....	2, 178, 405	684, 837	1, 544, 964	70, 359	....	....	5, 378, 829	865, 928	....
September 18	634, 545	371, 300	....	2, 840, 085	1, 056, 184	2, 002, 126	782, 315	....	....	5, 476, 756	2, 209, 799	....
September 25	1, 134, 135	479, 400	....	977, 895	1, 435, 944	2, 973, 266	449, 367	....	....	5, 085, 296	2, 364, 711	....

TABLE II.—RECEIPTS OF CRUDE AND REFINED PETROLEUM—Continued.

For week ending—	BY ERIE RAILWAY.			BY HUDSON RIVER RAILROAD.		BY PENNSYLVANIA RAILWAY.			CANAL.	TOTAL.		
	Crude.	Refined.	Naphtha.	Crude.	Refined.	Crude.	Refined.	Naphtha.	Crude.	Crude.	Refined.	Naphtha.
1879.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
October 2	991, 485	564, 000	....	2, 601, 360	1, 404, 783	2, 388, 762	450, 100	....	....	5, 981, 607	2, 418, 883	....
October 9	535, 185	826, 730	....	1, 088, 325	792, 796	2, 227, 820	402, 057	....	....	3, 851, 330	2, 021, 583	....
October 16	455, 400	1, 312, 788	....	280, 575	551, 733	1, 840, 110	240, 358	....	....	2, 576, 085	2, 104, 879	....
October 23	1, 297, 575	633, 090	....	358, 830	689, 302	2, 516, 842	93, 718	....	....	4, 173, 247	1, 416, 110	....
October 30	1, 704, 960	593, 093	....	1, 019, 225	1, 226, 465	2, 916, 481	11, 938	....	....	5, 640, 666	1, 831, 496	....
November 6	1, 246, 680	84, 224	....	843, 210	487, 625	2, 778, 771	34, 028	....	....	4, 868, 661	605, 877	....
November 13	1, 871, 640	745, 796	....	781, 920	752, 705	2, 608, 972	74, 307	....	....	5, 262, 532	1, 527, 808	....
November 20	2, 614, 590	587, 453	....	683, 910	656, 138	1, 910, 763	667, 024	....	....	5, 209, 263	1, 910, 615	....
November 27	2, 166, 435	560, 522	....	719, 585	596, 195	1, 781, 129	252, 531	....	....	4, 667, 049	1, 409, 248	....
December 4	1, 568, 340	629, 988	....	726, 930	287, 311	3, 773, 693	736, 866	....	....	6, 068, 963	1, 654, 165	....
December 11	1, 192, 230	379, 525	....	1, 364, 040	492, 137	2, 365, 794	306, 205	....	....	4, 922, 064	1, 177, 867	....
December 18	1, 192, 275	379, 713	....	1, 235, 475	250, 510	2, 007, 899	299, 249	....	....	4, 435, 649	929, 472	....
December 25	2, 349, 360	1, 044, 105	....	861, 480	623, 643	2, 154, 420	32, 900	....	....	5, 365, 260	1, 700, 648	....
December 31	2, 859, 795	1, 744, 452	....	887, 805	364, 062	2, 618, 748	35, 673	....	....	6, 366, 348	2, 144, 187	....
1880.												
January 8	2, 495, 655	1, 193, 850	....	1, 039, 140	794, 100	4, 051, 321	107, 771	....	....	7, 586, 116	2, 095, 721	....
January 15	3, 411, 810	963, 200	....	1, 158, 120	440, 950	3, 288, 166	401, 756	....	....	7, 856, 096	1, 805, 906	....
January 22	2, 306, 205	501, 250	....	1, 306, 170	340, 100	1, 386, 682	438, 050	....	....	4, 999, 057	1, 279, 400	....
January 29	2, 708, 460	653, 300	66, 150	1, 369, 980	221, 800	2, 601, 312	254, 350	....	....	6, 679, 752	1, 129, 450	66, 150
February 5	1, 562, 805	368, 750	....	1, 392, 668	156, 600	3, 683, 581	210, 200	....	....	6, 639, 054	735, 550	....
February 12	2, 336, 680	181, 300	....	1, 309, 005	173, 500	3, 301, 056	89, 450	....	....	6, 946, 841	444, 250	....
February 19	2, 263, 320	51, 300	....	1, 786, 185	109, 500	2, 451, 109	19, 500	....	....	6, 500, 714	180, 300	....
February 26	1, 873, 170	41, 100	....	1, 485, 495	136, 900	2, 453, 912	11, 600	....	....	5, 812, 577	189, 600	....
March 4	1, 482, 840	30, 900	47, 150	1, 934, 820	96, 250	3, 663, 640	2, 500	....	....	7, 081, 000	129, 650	47, 150
March 11	48, 500	2, 983, 950	89, 350	1, 886, 625	112, 750	3, 040, 501	6, 750	....	....	4, 976, 626	3, 103, 450	89, 350
March 18	3, 701, 520	2, 800	59, 150	2, 088, 755	108, 600	3, 442, 571	27, 500	....	....	9, 232, 846	138, 900	59, 150
March 25	3, 074, 220	2, 800	132, 850	1, 779, 345	171, 300	3, 201, 898	5, 000	....	....	8, 055, 463	179, 100	132, 850
April 1	2, 834, 100	1, 302, 500	......	2, 066, 445	428, 100	3, 626, 020	2, 500	....	....	8, 526, 565	1, 733, 100	....
April 8	1, 124, 910	....	....	1, 310, 445	714, 700	2, 122, 824	16, 000	....	....	4, 557, 539	730, 700	....
April 15	817, 875	2, 650	......	595, 620	71, 000	411, 573	....	....	....	1, 825, 468	73, 650	....
April 22	1, 711, 845	....	......	444, 815	44, 000	1, 144, 611	2, 500	....	....	3, 301, 271	46, 500	....
April 29	2, 195, 280	19, 450	....	716, 500	32, 000	208, 583	5, 000	....	....	3, 120, 363	56, 450	....
May 6	1, 097, 640	38, 700	....	1, 727, 010	96, 000	777, 995	2, 500	....	....	3, 602, 645	137, 200	....
May 13	2, 803, 770	......	....	1, 751, 670	140, 000	450, 614	17, 400	....	....	5, 006, 054	157, 400	....
May 20	3, 674, 385	35, 300	....	1, 733, 400	108, 000	617, 924	6, 600	....	....	6, 025, 709	149, 900	....
May 27	4, 367, 835	16, 050	......	1, 519, 200	78, 100	250, 314	7, 500	....	....	6, 137, 349	101, 650	....
Total, census year.	91, 675, 935	29, 894, 360	394, 650	73, 965, 518	38, 459, 426	118, 332, 563	15, 732, 688	....	1, 767, 757	285, 740, 033	84, 041, 483	394, 650
Total, 1880	119, 842, 560	19, 271, 650	1, 061, 250	80, 825, 203	18, 439, 950	56, 210, 897	5, 135, 977	....	....	256, 878, 660	42, 847, 577	1, 553, 850
Total, 1879	77, 580, 610	28, 460, 996	256, 620	68, 061, 215	43, 657, 858	98, 434, 951	15, 406, 718	394, 337	2, 830, 045	246, 906, 821	87, 525, 572	650, 957
Total, 1878	67, 263, 973	20, 541, 352	664, 380	47, 579, 410	42, 389, 953	68, 110, 155	15, 873, 717	....	7, 103, 634	189, 708, 589	79, 600, 602	....
Total, 1877	63, 734, 244	51, 117, 982	860, 850	36, 882, 450	45, 319, 665	78, 597, 550	7, 184, 614	....	....	179, 214, 244	103, 662, 216	....

TABLE III.—EXPORTS OF PETROLEUM AND PETROLEUM PRODUCTS FROM NEW YORK TO FOREIGN PORTS FOR 1878, 1879, 1880, AND THE CENSUS YEAR.

[From the reports of the New York Petroleum Exchange.]

REFINED PETROLEUM. 1 barrel = 50 gallons.

	1878.		1879.		1880.		Census year.	
	Gallons.	Barrels.	Gallons.	Barrels.	Gallons.	Barrels.	Gallons.	Barrels.
Great Britain:								
London	13, 158, 980	263, 180	21, 192, 079	423, 842	14, 026, 865	280, 537	22, 367, 521	447, 350
Liverpool	5, 013, 377	100, 268	7, 993, 254	159, 865	6, 482, 959	129, 659	8, 943, 434	178, 869
Bristol	2, 537, 886	50, 758	4, 280, 209	85, 604	4, 195, 827	83, 917	3, 299, 266	65, 985
Ireland	5, 444, 392	108, 888	7, 158, 319	143, 166	4, 261, 677	85, 234	6, 967, 157	139, 343
Other ports	3, 277, 117	65, 542	5, 266, 440	105, 329	3, 935, 042	78, 701	4, 639, 210	92, 784
Germany:								
Bremen	28, 279, 351	565, 587	40, 035, 341	800, 707	43, 953, 350	879, 067	47, 494, 457	949, 889
Hamburg	7, 971, 865	159, 437	11, 638, 166	232, 766	15, 344, 524	306, 890	11, 925, 646	238, 513
Königsburg and Stettin	7, 977, 223	159, 544	7, 425, 684	148, 514	3, 430, 726	68, 615	7, 036, 048	140, 721
Dantzic	3, 386, 423	67, 728	1, 874, 059	37, 481	804, 144	16, 083	1, 149, 168	22, 983
Other ports	739, 317	14, 786	1, 940, 384	38, 808	334, 550	6, 691	1, 094, 486	21, 890
Norway and Sweden	3, 928, 374	78, 567	5, 480, 157	109, 603	5, 771, 784	115, 436	5, 704, 219	114, 084
Russia	1, 811, 288	36, 226	2, 670, 900	53, 418	1, 024, 632	20, 493	2, 062, 717	41, 254
Denmark	5, 886, 528	117, 731	5, 809, 642	116, 193	8, 120, 126	162, 403	5, 038, 410	100, 768
Belgium	10, 909, 641	218, 193	16, 156, 629	323, 133	18, 560, 737	371, 215	17, 640, 481	352, 810
Holland	8, 623, 656	172, 473	11, 010, 971	220, 219	11, 858, 877	237, 178	11, 421, 878	228, 438
Spain	6, 658, 785	133, 176	7, 693, 336	153, 867	2, 618, 769	52, 375	7, 163, 521	143, 270
Portugal	1, 356, 800	27, 136	1, 973, 427	39, 469	1, 336, 379	26, 728	1, 735, 029	34, 701
Gibraltar and Malta	2, 480, 342	49, 607	1, 857, 396	37, 148	2, 573, 923	51, 478	1, 746, 220	34, 924
Italy	3, 018, 291	60, 366	2, 331, 628	46, 633	1, 960, 057	39, 201	2, 161, 160	43, 223
Trieste	5, 807, 423	116, 148	9, 787, 224	195, 744	10, 142, 010	202, 840	8, 967, 587	179, 352
Greece	1, 594, 220	31, 884	1, 513, 650	30, 273	334, 310	6, 686	1, 205, 250	24, 105
Turkey in Europe	4, 453, 916	89, 078	3, 605, 440	72, 109	1, 727, 350	34, 547	3, 048, 380	60, 968
Turkey in Asia	2, 803, 850	56, 077	1, 404, 660	28, 093	660, 990	13, 220	1, 331, 160	26, 623
India	....	....	7, 588, 460	151, 769	9, 120, 710	182, 414	13, 178, 760	263, 575
China and Japan	24, 271, 545	585, 431	18, 803, 770	376, 075	6, 751, 392	135, 028	17, 021, 352	340, 427
East Indies	8, 861, 345	177, 227	22, 145, 090	442, 902	14, 949, 765	298, 995	26, 926, 105	538, 522
Africa:								
Alexandria	1, 555, 666	31, 113	3, 616, 633	72, 333	2, 203, 620	44, 072	2, 829, 560	56, 591
Canary islands	109, 033	2, 181	72, 976	1, 460	74, 095	1, 482	88, 974	1, 779
Other ports	1, 719, 518	34, 390	2, 359, 170	47, 183	2, 077, 655	41, 553	2, 798, 510	55, 970
Australia	2, 476, 982	49, 540	2, 277, 346	45, 547	1, 910, 324	38, 206	2, 954, 956	59, 099
New Zealand	811, 993	16, 240	352, 260	7, 045	565, 482	11, 310	328, 730	6, 575
Sandwich Islands	32, 000	640	45, 850	917	74, 000	1, 480	64, 000	1, 280
South America:								
Brazil	3, 388, 078	67, 762	4, 215, 973	84, 319	4, 036, 859	80, 737	3, 986, 652	79, 733
Argentine Confederation	1, 632, 985	32, 660	1, 659, 210	33, 184	2, 060, 810	41, 216	1, 705, 210	34, 104
Chili and Peru	1, 062, 115	21, 242	926, 872	18, 537	334, 123	6, 682	638, 993	12, 780
United States of Colombia	2, 640	53	38, 060	761	42, 068	841	42, 946	859
Venezuela	403, 682	8, 074	523, 958	10, 479	672, 162	13, 443	483, 220	9, 664
Other ports	13, 500	270	26, 100	522	31, 496	630	45, 477	910
Central America	162, 244	3, 245	215, 383	4, 308	239, 680	4, 794	232, 355	4, 647
Mexico	532, 921	10, 658	784, 483	15, 690	696, 359	13, 927	735, 613	14, 712
British North America	412, 329	8, 247	237, 654	4, 753	171, 337	3, 427	126, 835	2, 537
Cuba	2, 117, 267	42, 345	703, 186	14, 064	433, 528	8, 671	430, 839	8, 617
British West Indies	1, 222, 602	24, 452	1, 386, 679	27, 734	1, 263, 614	25, 272	1, 339, 438	26, 789
Other West Indies	801, 449	16, 029	968, 776	19, 376	928, 393	18, 568	929, 361	18, 587
Totals	188, 708, 939	3, 774, 179	249, 046, 884	4, 980, 938	212, 097, 080	4, 241, 942	261, 030, 291	5, 220, 606

CRUDE PETROLEUM. 1 barrel = 42 gallons.

	1878.		1879.		1880.		Census year.	
	Gallons.	Barrels.	Gallons.	Barrels.	Gallons.	Barrels.	Gallons.	Barrels.
France:								
Havre	5, 862, 304	139, 579	7, 803, 090	185, 788	7, 687, 297	183, 031	7, 994, 545	190, 346
Marseilles	1, 765, 159	42, 028	2, 041, 059	48, 596	2, 116, 256	50, 387	2, 038, 590	48, 538
Bordeaux	1, 449, 115	34, 503	2, 464, 332	58, 675	1, 853, 088	44, 121	2, 208, 468	52, 583
Dunkirk	2, 929, 780	69, 733	2, 704, 475	64, 392	3, 831, 438	91, 225	3, 278, 011	78, 048
Other ports	629, 319	14, 984	2, 752, 155	65, 527	4, 039, 696	96, 183	2, 938, 081	69, 954
Antwerp	170, 320	4, 055	140, 506	3, 345	322, 115	7, 669	140, 506	3, 345
Bremen	1, 102, 060	26, 240	2, 133, 847	50, 806	3, 703, 109	88, 169	2, 773, 370	66, 023
Norway and Sweden	46, 324	1, 103	....	....	51, 968	1, 237	....	....
Spain	277, 072	6, 597	1, 873, 167	44, 599	8, 694, 381	207, 009	2, 913, 881	69, 378
Cuba	344, 786	8, 209	1, 614, 300	38, 436	1, 610, 710	38, 350	1, 297, 500	30, 893
Other ports	....	....	....	....	486	12	486	12
Totals	14, 576, 239	347, 053	23, 526, 931	560, 165	33, 910, 544	807, 394	25, 583, 438	609, 130

TABLE III.—EXPORTS OF PETROLEUM AND PETROLEUM PRODUCTS—Continued.

NAPHTHA. 1 barrel = 50 gallons.

	1878.		1879.		1880.		Census year.	
	Gallons.	Barrels.	Gallons.	Barrels.	Gallons.	Barrels.	Gallons.	Barrels.
Great Britain	4, 915, 361	98, 307	7, 497, 559	149, 951	6, 152, 564	123, 051	7, 024, 509	140, 490
France	2, 372, 820	47, 456	4, 864, 165	97, 283	4, 624, 955	92, 499	6, 768, 300	135, 366
Germany	712, 531	14, 251	937, 995	18, 760	781, 566	15, 631	1, 130, 037	22, 601
Other European ports	1, 304, 755	26, 095	1, 800, 010	36, 000	1, 053, 883	21, 078	1, 777, 404	35, 548
Various ports	109, 916	2, 198	81, 567	1, 631	68, 692	1, 374	74, 009	1, 480
Totals	9, 415, 383	188, 308	15, 181, 296	303, 626	12, 681, 660	253, 633	16, 774, 259	335, 485

RESIDUUM. 1 barrel = 50 gallons.

	1878. Gallons.	1878. Barrels.	1879. Gallons.	1879. Barrels.	1880. Gallons.	1880. Barrels.	Census year. Gallons.	Census year. Barrels.
To all ports	2, 617, 039	52, 341	4, 177, 704	83, 554	2, 863, 552	57, 271	4, 135, 260	82, 705

SUMMARY.

	1878.		1879.		1880.		Census year.	
Total refined, crude equivalent	251, 611, 919	......	332, 062, 500	......	282, 796, 100	......	348, 040, 400	......
Total crude	14, 576, 239	......	23, 526, 931	......	33, 910, 544	......	25, 583, 438	......
Total from New York, crude equivalent	266, 188, 158	......	355, 589, 431	......	316, 706, 644	......	373, 623, 838	......

EXPORTS OF PETROLEUM AND PETROLEUM PRODUCTS FROM PHILADELPHIA TO FOREIGN PORTS FOR 1877, 1878, 1879, AND 1880.

[From the report of the New York Produce Exchange.]

	1877.	1878.	1879.	1880.
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*
United Kingdom	2, 812, 745	4, 340, 407	2, 037, 860	2, 342, 234
Northern Europe	32, 159, 144	47, 539, 968	50, 542, 743	41, 539, 471
Mediterranean ports	13, 728, 475	18, 884, 404	26, 691, 586	8, 763, 135
East Indies	208, 881	......	......	204, 509
China and Japan	216, 500	2, 840, 000	1, 855, 250	1, 342, 100
South and Central America	29, 617	29, 815	361, 646	22, 695
West Indies	274, 821	32, 100	58, 448	5, 000
British North America	3, 450	277, 268	......	......
Other countries	......	......	......	454, 901
Totals	49, 433, 633	73, 943, 962	81, 547, 533	54, 673, 940

TABLE IV.—THE CHARTERS REPORTED FOR CRUDE AND REFINED PETROLEUM, NAPHTHA, AND RESIDUUM FROM NEW YORK, PHILADELPHIA, BOSTON, BALTIMORE, RICHMOND, AND PORTLAND TO THE DIFFERENT PORTS OF THE WORLD, EXCLUSIVE OF NORTH AMERICA, DURING THE CENSUS YEAR.

[From the reports of the New York Petroleum Exchange.]

	REFINED.		NAPHTHA.		CRUDE.		RESIDUUM.	
	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.
Aarhuus	3, 000	......	......	......	......	......	......	......
Adriatic sea	7, 000	102, 000	......	......	......	......	......	......
Adelaide	......	5, 000	......	......	......	......	......	......
Alexandria	......	209, 000	......	......	......	......	......	......
Alicante	500	98, 000	......	......	......	13, 600	......	......
Algiers	200	27, 000	......	......	......	......	......	......
Amsterdam	45, 700	......	......	......	......	......	......	......
Ancona	300	25, 000	......	......	......	......	......	......
Anjier	......	889, 000	......	......	......	......	......	......
Antwerp	552, 800	1, 000	23, 500	10, 000	11, 000	......	300	......
Baltic ports	361, 650	......	......	......	......	......	......	......
Barcelona	......	......	......	......	3, 300	......	......	......
Bari	......	18, 000	......	......	......	......	......	......
Belfast	20, 700	......	......	......	......	......	......	......
Bergen	8, 800	......	......	......	......	......	......	......
Beyrout	......	12, 000	......	......	......	......	......	......
Bilboa	7, 600	8, 000	......	......	16, 200	158, 000	......	......
Blaye	......	......	3, 500	......	49, 100	......	......	......
Bombay	......	627, 800	......	......	......	......	......	......
Bona	......	6, 000	......	......	......	......	......	......

TABLE IV.—THE CHARTERS REPORTED FOR CRUDE AND REFINED PETROLEUM, ETC.—Continued.

	REFINED.		NAPHTHA.		CRUDE.		RESIDUUM.	
	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.
Bordeaux			19, 550		39, 400			
Bremen	1, 337, 106		23, 200		30, 800			
Bristol	60, 100		18, 850					
Cadiz	500	35, 800						
Cagliari		12, 000						
Calcutta		477, 000						
Cartagena		30, 000						
Cette					12, 400			
China		215, 000						
Christiana	15, 200							
Civita Vecchia		11, 000						
Constantinople		140, 000						
Continent of Europe	706, 500		10, 300		18, 500			
Copenhagen	32, 200							
Corfu		34, 000						
Cork	108, 100				5, 000			
Corunna		6, 000			14, 200			
Cronstadt	10, 950							
Dantzig	21, 700							
Drontheim	2, 800							
Drummen	1, 500							
Dublin	19, 200							
Dunkirk					74, 500			
Dutch ports	30, 100							
East Indies		153, 000						
East Indies, British		25, 000						
Elsinore	60, 400							
Exeter	9, 950		9, 800					
Exmouth			1, 700					
Flensborg	2, 200							
French ports			2, 000	4, 900	3, 500			
Galway	3, 000							
Gefle	2, 400							
Genoa	26, 600	150, 000						
German ports	5, 500							
Gibraltar		18, 500						
Gottenburg	30, 700		1, 000					
Hamburg	221, 750							
Havre			52, 800		185, 700			
Hiogo		50, 000						
Hong-Kong		82, 500						
Hull	9, 000		3, 300					
Ireland, east coast	21, 350							
Italian ports	3, 000							
Japan		806, 000						
Java		1, 666, 000						
Königsburg	6, 000							
Leghorn	10, 000	40, 000						
Levant		186, 000						
Limerick	5, 000							
Lisbon	13, 709	6, 000						
Liverpool	185, 400		19, 500				82, 400	
London	616, 300		50, 700				7, 500	
Malaga		43, 000						
Malino	2, 200							
Malta		15, 000						
Manila		17, 000						
Marseilles		7, 000	600		61, 560		2, 000	
Mauritius		25, 000						
Mediterranean ports	50, 800	602, 500			7, 509			
Messina		37, 000						
Montevideo		10, 000						
Naples	27, 600	8, 000						
Newcastle	7, 600							
New Zealand		20, 000						

TABLE IV.—THE CHARTERS REPORTED FOR CRUDE AND REFINED PETROLEUM, ETC.—Continued.

	REFINED.		NAPHTHA.		CRUDE.		RESIDUUM.	
	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.
Norway	4,300							
Odessa		48,000						
Oporto	18,800	11,000						
Oran	800	12,000						
Palermo		49,000						
Passages					17,000	2,000		
Piræus		31,000						
Palmas	1,000	21,000						
Penang		20,000						
Phillipsville		8,000						
Plymouth	2,000		2,200					
Port d'Galle		95,000						
Port Philip Head		45,000						
Port Said		21,000						
Rangoon		151,500						
Riga	3,000							
Rivadeo		1,000						
Rostock	2,200							
Rotterdam	101,500							
Rouen			3,000		39,200			
Sables d'Oloun					2,500			
Saigon		22,000						
Salonica		128,000						
Santander	2,100	13,000						
Santos		7,000						
Seville	200	15,900						
Shanghai		353,000						
Sicily		27,000						
Singapore		112,000						
Smyrna		73,500						
South Africa		6,000						
Spanish ports	10,100	53,000			5,500	2,000		
Stockholm	5,000							
Sundsval	2,700							
Swedish ports	2,200							
Tarragona	2,100				5,200	16,000		
Tarranti		8,000						
Toulon					2,200			
Tralee	1,500							
Trieste	268,966							
United Kingdom	148,950							
Valencia	4,600	27,750						
Venice	9,300	38,000						
Vigo		50,000						
Volo		12,000						
Yokohama		172,000						
Zante		8,200						
Zanzibar		45,000						
Totals	5,265,981	8,640,950	245,500	14,900	604,269	191,600	92,200	

	Barrels of 50 gallons each.	Gallons.
Refined:		
In barrels	5,265,981	349,758,550
In cases	1,729,190	
Naphtha:		
In barrels	245,500	12,424,000
In cases	2,980	
Crude:		
In barrels	604,269	32,129,450
In cases	38,320	
Residuum:		
In barrels	92,200	4,610,000
	7,978,440	398,922,000

TABLE V.—PETROLEUM AND ITS PRODUCTS EXPORTED FROM THE UNITED STATES DURING THE YEARS ENDING JUNE 30, 1879 AND 1880.

[From report of Bureau of Statistics.]

	NEW YORK.		PHILADELPHIA.		BALTIMORE.		BOSTON.		OTHER PORTS.		TOTAL.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Gallons.	*Dollars.*	*Gallons.*	*Dollars.*	*Gallons.*	*Dollars.*	*Gallons.*	*Dollars.*	*Gallons.*	*Dollars.*	*Gallons.*	*Dollars.*
Crude	17, 716, 883	1, 517, 701	4, 687, 786	377, 197	1, 166, 825	98, 292	....	....	2, 302, 994	187, 223	25, 874, 488	2, 180, 413
Naphtha	11, 477, 029	987, 145	2, 729, 037	207, 928	600, 782	42, 500	52, 750	4, 623	194, 763	16, 584	15, 054, 361	1, 258, 780
Illuminating	206, 520, 009	23, 088, 504	76, 307, 729	7, 795, 749	32, 662, 045	3, 231, 700	5, 090, 871	640, 553	11, 005, 788	1, 243, 356	331, 586, 442	35, 999, 862
Lubricating	1, 709, 556	452, 257	7, 182	3, 367	269, 759	56, 249	478, 998	134, 903	22, 186	8, 692	2, 487, 681	655, 468
Residuum	2, 684, 052	173, 563	144, 564	7, 952	216, 342	12, 693	....	....	262, 080	16, 518	3, 307, 038	210, 726
Total, 1879	240, 107, 529	26, 219, 170	83, 876, 298	8, 392, 193	34, 915, 753	3, 441, 434	5, 622. 619	780, 079	13, 787, 811	1, 472, 373	378, 310, 010	40, 305, 249
Crude	24, 034, 260	1, 652, 200	2, 730, 147	160, 549	....	....	500	65	1, 533, 090	114, 393	28, 297, 997	1, 927, 207
Naphtha	15, 257, 520	996, 398	2, 366, 622	148, 464	682, 702	36, 200	385	93	103, 815	11, 074	18, 411, 044	1, 192, 229
Illuminating	266, 841, 227	23, 489, 496	77, 083, 630	6, 234, 608	17, 921, 548	1, 399, 975	4, 611, 433	507, 511	867, 985	151, 985	367, 325, 823	31, 783, 575
Lubricating	4, 151, 597	822, 388	34, 943	6, 980	367, 240	68, 713	600, 837	137, 378	8, 218	3, 665	5, 162, 835	1, 039, 124
Residuum	3, 885, 588	217, 677	395, 094	28, 161	416, 430	24, 000	....	....	69, 888	6, 652	4, 767, 000	276, 490
Total, 1880	314, 170, 192	27, 178, 159	82, 610, 436	6, 578, 762	19, 387, 920	1, 528, 888	5, 213, 155	645, 047	2, 582, 996	287, 769	423, 964, 699	36, 218, 625

TABLE VI.—EXPORTS OF PETROLEUM AND PETROLEUM PRODUCTS FROM ALL UNITED STATES PORTS TO ALL FOREIGN COUNTRIES, AND THE DECLARED VALUE THEREOF, COMPILED FROM RETURNS OF THE UNITED STATES BUREAU OF STATISTICS.

[From the report of the New York Produce Exchange for 1880.]

Year.	CRUDE.		REFINED.		NAPHTHA, ETC.		RESIDUUM.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Gallons.	*Dollars.*	*Gallons.*	*Dollars.*	*Gallons.*	*Dollars.*	*Gallons.*	*Dollars.*
1873	19, 643, 740	2, 665, 771	209, 021, 305	41, 854, 841	10, 250, 547	1, 264, 962	2, 069, 616	145, 398
1874	14, 430, 851	1, 428, 494	208, 635, 382	30, 497, 191	10, 617, 268	997, 355	2, 263, 776	167, 794
1875	16, 536, 800	1, 738, 589	204, 616, 798	28, 417, 339	14, 048, 726	1, 392, 192	2, 655, 984	169, 671
1876	25, 343, 271	3, 343, 763	221, 900, 446	44, 448, 361	13, 252, 751	1, 502, 798	3, 273, 024	239, 461
1877	28, 772, 233	3, 267, 309	309, 778, 832	51, 901, 106	19, 565, 605	1, 938, 672	4, 778, 641	390, 077
1878	23, 883, 508	2, 150, 390	308. 896. 307	39, 094, 451	13, 431, 783	1, 077, 402	3, 145, 506	221, 019
1879	27, 841, 900	2, 182, 573	367, 321, 255	32, 696, 713	22, 695, 223	2, 081, 210	4, 457, 486	273, 045
1880	35, 481, 168	2, 679, 193	284, 470, 800	29, 126, 985	22, 010, 074	2, 615, 094	3, 324, 804	204, 324
Total	191, 933, 471	19, 456, 082	2, 114, 641, 125	298, 036, 987	125, 871, 977	12, 869, 685	25, 968, 837	1, 810, 789
Average	23, 991, 684	2, 432, 010	264, 330, 141	37, 254, 623	15, 733, 997	1, 608, 711	3, 246, 105	226, 349
CENSUS YEAR.								
1879.								
June	1, 350, 713	102, 755	30, 221, 930	2, 719, 090	1, 305, 136	129, 170	62, 664	3, 568
July	3, 297, 347	205, 781	44, 972, 481	3, 882, 095	1, 568, 370	136, 419	194, 082	14, 166
August	1, 483, 108	94, 086	41, 883, 762	3, 325, 565	2, 579, 406	207, 179	451, 500	26, 781
September	1, 496, 109	135, 931	40, 046, 705	3, 092, 885	2, 187, 854	168, 749	328, 272	21, 615
October	2, 808, 561	163, 935	42, 837, 294	3, 530, 654	3, 651, 526	296, 224	758, 478	36. 364
November	2, 924, 488	187, 481	32, 684, 161	2, 810, 061	2, 047, 099	175, 141	769, 062	35, 530
December	3, 223, 457	248, 822	37, 455, 351	3, 352, 574	3, 794, 884	305, 022	594, 258	33, 029
1880.								
January	2, 299, 624	170, 399	34, 219, 503	3, 159, 460	1, 407, 958	158, 877	495, 768	39, 334
February	2, 756, 776	211, 236	20, 593, 427	1, 934, 975	1, 030, 129	146, 119	582, 330	31, 035
March	1, 945, 020	136, 152	20, 545, 746	1, 939, 466	2, 059, 438	280, 083	410, 718	22, 641
April	1, 745, 150	121, 418	18, 130, 976	1, 724, 732	1, 129, 941	162, 784	2, 604	248
May	1, 645, 181	121, 887	13, 090, 549	1, 150, 665	897, 004	102, 064	187, 152	10, 199
Total	26, 975, 534	1, 899, 883	376, 681, 885	32, 622, 222	23, 658, 745	2, 267, 831	4, 836, 888	274, 510

TABLE VII.—QUANTITY OF PETROLEUM PRODUCED, AND THE QUANTITY AND VALUE OF PETROLEUM PRODUCTS EXPORTED FROM THE UNITED STATES DURING EACH FISCAL YEAR FROM 1864 TO 1880, INCLUSIVE.

[From the report of the New York Produce Exchange for 1880.]

Years ending June 30—	PRODUCTION.*		EXPORTS FROM THE UNITED STATES.											
	Barrels produced of 42 gallons each.	Gallons produced.	Crude oil, including all natural oils, without regard to gravity.		Mineral, refined or manufactured.						Residuum (tar, pitch, and all other from which the light bodies have been distilled).		Total.	
					Naphtha, benzine, gasoline, etc.		Illuminating.		Lubricating (heavy paraffine, etc.).					
			Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.
1864 ...	2,478,709	104,105,778	9,980,654	3,864,187	438,197	154,091	12,791,518	6,764,411	....	....	....	....	23,210,369	10,782,689
1865....	2,424,905	101,846,010	12,293,897	6,868,513	480,947	173,943	12,722,005	9,520,957	....	....	....	....	25,496,849	16,563,413
1866....	3,165,700	132,959,400	16,057,943	6,015,921	673,477	188,825	34,255,921	18,626,141	....	....	....	....	50,987,341	24,830,887
1867....	3,591,900	150,859,800	7,344,248	1,864,001	224,576	34,175	62,686,657	22,509,466	....	....	....	....	70,255,481	24,407,642
1868....	3,613,709	151,775,778	10,029,659	1,564,933	1,517,268	267,873	67,909,961	19,977,870	....	....	....	....	79,456,888	21,810,676
1869 ...	4,046,558	169,955,436	13,425,566	2,994,404	2,673,094	445,770	84,403,492	27,636,137	†134,532	51,122	....	....	100,636,684	31,127,433
1870....	4,411,016	185,262,672	10,403,314	2,237,292	5,422,604	564,864	97,902,505	29,864,193	†6,871	2,611	....	....	113,735,294	32,608,960
1871 ...	5,558,775	233,468,550	9,859,038	1,971,847	7,209,592	746,797	132,608,955	34,138,736	†59,632	22,660	†155,474	14,770	149,892,691	36,894,810
1872 ...	5,842,497	245,384,874	13,559,768	2,307,111	8,092,635	932,160	122,539,575	30,566,108	541,419	211,287	438,186	41,724	145,171,583	34,058,390
1873....	7,242,343	304,178,406	18,439,407	3,010,050	9,743,593	1,487,439	158,102,414	37,195,735	748,699	277,966	781,074	79,566	187,815,187	42,050,756
1874 ...	11,188,741	469,927,122	17,776,419	2,099,696	9,737,457	1,038,622	217,220,504	37,560,995	1,244,305	404,243	1,827,798	142,299	247,806,483	41,245,855
1875....	10,083,828	423,520,776	14,718,114	1,406,018	11,758,940	1,141,440	191,551,933	27,030,361	1,173,473	313,646	2,752,848	187,103	221,955,308	30,078,568
1876....	8,823,142	370,571,964	20,520,397	2,220,268	14,780,236	1,442,811	204,814,673	28,755,638	963,442	303,863	2,581,404	193,206	243,660,152	32,915,786
1877 ...	10,822,871	454,560,582	26,819,202	3,756,729	15,140,183	1,816,682	262,441,844	55,401,132	1,601,065	497,540	3,196,620	317,355	309,198,914	61,789,438
1878....	14,738,262	619,007,004	26,936,727	2,694,018	16,416,621	1,411,812	289,214,541	41,513,676	2,304,624	639,381	3,968,790	316,087	338,841,303	46,574,974
1879....	16,917,606	710,539,452	25,874,488	2,180,413	15,054,361	1,258,780	331,586,442	35,999,862	2,487,681	655,468	3,307,038	210,726	378,310,010	40,305,249
1880....	22,382,509	940,065,378	28,297,997	1,927,207	18,411,044	1,192,229	367,325,823	31,783,575	5,162,835	1,039,124	4,767,000	276,490	423,964,699	36,218,625

* As a given number of gallons of refined petroleum represents the product of a larger number of gallons of crude petroleum, it is necessary to reduce the exports of petroleum to their equivalent in crude oil in order to arrive at a knowledge of the percentage of the total product of mineral oil exported.

† Estimated.

TABLE VIII.—NEW YORK PETROLEUM MARKET.

AVERAGE PRICES PER YEAR.

[From reports of the New York Produce Exchange.]

Year.	CRUDE IN BULK, PER GALLON.		CRUDE IN BARRELS, PER GALLON.		REFINED STANDARD WHITE, PER GALLON.		NAPHTHA IN BARRELS, PER GALLON.	
	Extremes.	Average price.	Extremes.	Average price.	Extremes.	Average price.	Extremes.	Average price.
	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.
1873	....	7.62	....	....	....	18.21	....	11.07
1874	....	5.92	....	....	....	13.09	....	9.04
1875	....	6.52	....	....	....	12.92	....	9.67
1876	....	10.53	....	10.50	....	19.19	....	11.36
1877	....	9.09	....	9.12	....	15.72	....	9.75
1878	....	6.86	....	6.37	....	10.77	....	7.13
1879	....	3.62	....	7.10	....	8.08	....	6.40
1880	....	7.14	....	7.14	....	9.12	....	7.62
CENSUS YEAR, 1879.								
June	....	3.60	5 to $7\frac{3}{4}$	6.44	$6\frac{5}{8}$ to $7\frac{3}{8}$	7.23	5 to 8	6.42
July	....	2.50	5 to $6\frac{1}{4}$	5.41	$6\frac{5}{8}$ to $7\frac{3}{8}$	6.97	4 to 6	5.14
August	....	2.38	$4\frac{7}{8}$ to $6\frac{1}{4}$	5.42	$6\frac{1}{8}$ to $7\frac{1}{2}$	6.57	4 to 5	4.50
September	....	2.50	$4\frac{7}{8}$ to $6\frac{3}{8}$	5.50	$6\frac{1}{4}$ to $7\frac{1}{2}$	6.79	4 to 5	4.62
October	....	3.10	$5\frac{3}{8}$ to $7\frac{1}{2}$	6.55	7 to $7\frac{7}{8}$	7.43	$4\frac{1}{2}$ to 6	5.23
November	....	3.90	$6\frac{1}{2}$ to $8\frac{1}{2}$	7.45	$7\frac{1}{8}$ to $8\frac{7}{8}$	8.03	6 to $6\frac{3}{4}$	6.27
December	....	....	$7\frac{1}{2}$ to $8\frac{1}{2}$	7.92	$8\frac{1}{4}$ to 9	8.56	$6\frac{1}{2}$ to $6\frac{3}{4}$	6.63
1880.								
January	$7\frac{1}{16}$ to 8	7.53	7 to $8\frac{3}{8}$	7.55	$7\frac{1}{2}$ to $8\frac{1}{2}$	7.94	$6\frac{1}{2}$ to 7	6.71
February	$6\frac{7}{8}$ to $7\frac{11}{16}$	7.03	$6\frac{5}{8}$ to $7\frac{3}{4}$	7.29	$7\frac{5}{8}$ to 8	7.81	$6\frac{1}{4}$ to 7	6.65
March	$6\frac{9}{16}$ to $7\frac{5}{16}$	6.68	$6\frac{1}{2}$ to $7\frac{1}{2}$	6.11	$7\frac{5}{8}$ to $7\frac{7}{8}$	7.75	$5\frac{1}{2}$ to $6\frac{3}{4}$	6.06
April	$6\frac{13}{16}$ to $7\frac{5}{8}$	6.97	$6\frac{5}{8}$ to $7\frac{3}{4}$	7.22	$7\frac{1}{2}$ to $7\frac{7}{8}$	7.56	$5\frac{1}{2}$ to $5\frac{3}{4}$	5.68
May	$6\frac{7}{16}$ to $7\frac{5}{8}$	7.03	$6\frac{1}{4}$ to $7\frac{3}{4}$	7.03	$7\frac{3}{8}$ to $7\frac{3}{4}$	7.56	$5\frac{1}{2}$ to $5\frac{1}{2}$	5.50

TABLE IX.—IMPORTS OF REFINED PETROLEUM AT FIVE PRINCIPAL PORTS OF THE UNITED KINGDOM.

[From reports of the New York Produce Exchange.]

	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
London	247, 024	169, 394	227, 305	348, 412	261, 385	492, 292	369, 259	....
Liverpool	157, 700	94, 170	145, 679	144, 000	136, 059	203, 500	163, 800	....
Bristol	37, 175	36, 460	52, 792	65, 584	54, 267	93, 485	90, 622	....
Hull	10, 331	6, 902	24, 657	26, 365	25, 420	30, 884	34, 057	....
Exeter	19, 319	18, 175	7, 598	8, 911	13, 103	10, 789	....	....
Total	471, 549	325, 101	458, 031	593, 272	490, 234	830, 950	657, 738	....

STOCKS AT SAME PORTS, JANUARY 1.

	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.
London	....	117, 345	41, 193	40, 078	94, 326	61, 500	160, 000	99, 518
Liverpool	....	62, 400	14, 500	22, 880	26, 700	21, 089	48, 000	32, 000
Bristol	....	8, 000	6, 500	11, 699	14, 000	3, 000	17, 000	20, 000
Hull	....	5, 444	350	650	4, 050	2, 300	800	1, 300
Exeter	....	3, 577	2, 200	612	921	1, 300	1, 134	....
Total	....	196, 766	64, 743	75, 919	139, 997	89, 189	226, 934	152, 818

TABLE X.—IMPORTS OF PETROLEUM AT THE UNDERMENTIONED EUROPEAN PORTS FOR SEVEN YEARS ENDED DECEMBER 31.

[From reports of the New York Produce Exchange.]

At—	1874.	1875.	1876.	1877.	1878.	1879.	1880.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
Hamburg	....	154, 581	131, 822	324, 936	293, 600	408, 869	525, 974
Antwerp	617, 338	720, 637	603, 251	840, 086	834, 400	649, 845	719, 017
Rotterdam	1, 885, 260	158, 214	177, 988	229, 258	219, 293	189, 850	212, 433
Amsterdam	110, 198	121, 261	65, 507	65, 026	132, 708	150, 209	217, 046
Bremen	811, 121	1, 043, 137	969, 971	1, 463, 264	1, 165, 746	1, 345, 772	1, 324, 591
Stettin	189, 476	228, 547	211, 875	204, 214	208, 767	249, 469	276, 515
Dantzic	67, 019	101, 848	83, 793	143, 620	111, 422	102, 474	107, 849
Königsburg	85, 937	121, 114	86, 207	116, 455	79, 198	79, 345	72, 223
St. Petersburg (*a*)	105, 399	68, 895	82, 914	121, 451	108, 105	101, 571	69, 652
Trieste (*b*)	113, 523	112, 822	145, 627	254, 644	199, 723	304, 392	273, 459
London	246, 323	169, 834	226, 432	333, 234	275, 707	380, 499	340, 717
Total barrels	4, 231, 594	3, 000, 890	2, 785, 387	4, 096, 188	3, 628, 669	3, 962, 295	4, 139, 476
a Includes 4 cases to barrel ....cases	59, 421	19, 701	60, 023	183, 160	48, 965	56, 707	33, 195
b Includes Baku ....barrels	....	....	21, 714	34, 517	38, 311	55, 694	52, 174

STOCKS OF PETROLEUM HELD AT THE SAME PLACE AND TIME.

	1874.	1875.	1876.	1877.	1878.	1879.	1880.
Hamburg	....	17, 640	9, 072	53, 726	22, 195	27, 749	86, 376
Antwerp	124, 643	109, 477	34, 160	106, 627	126, 894	109, 979	109, 338
Rotterdam	41, 203	15, 801	3, 124	35, 054	21, 954	11, 924	18, 540
Amsterdam	12, 344	10, 395	449	10, 737	32, 329	27, 874	50, 511
Bremen	199, 580	196, 365	42, 281	255, 907	225, 550	343, 738	559, 339
Stettin	20, 064	31, 335	24, 180	11, 598	16, 277	15, 305	42, 832
Dantzic	10, 891	17, 993	7, 118	37, 483	25, 833	20, 189	20, 295
Königsburg	10, 602	21,341	3, 328	21, 699	16, 160	14, 173	12, 956
St. Petersburg (*a*)	66, 886	41, 398	29, 115	55, 787	69, 786	60, 301	22, 108
Trieste	24, 200	4, 500	6, 350	47, 005	12, 970	37, 500	21, 600
London	117, 347	43, 035	36, 616	80, 481	59, 570	156, 786	99, 188
Total barrels	627, 760	509, 280	195, 793	716, 104	629, 518	825, 518	1, 043, 083
a Includes Baku	....	....	11, 782	10, 027	14, 412	18, 856	7, 315

TABLE XI.—THE VARIOUS PRODUCTS OF CRUDE OIL, INCLUDING PETROLEUM, CRUDE OIL, REFUSE OIL, AND GREASE, AND ALL PRODUCTS OF NAPHTHA, EXPORTED FROM BAKU FROM 1832 TO 1879, IN POODS OF 36 POUNDS EACH.

[From report New York Produce Exchange, 1880.]

Year.	Poods.	Year.	Poods.	Year.	Poods.	Year.	Poods.	Year.	Poods.
1832	261,000	1842	327,578	1852	No report	1862	No report	1872	1,535,990
1833	300,000	1843	327,167	1853	do	1863	340,000	1873	3,400,000
1834	346,109	1844	332,854	1854	do	1864	538,966	1874	5,000,000
1835	352,720	1845	31,685	1855	do	1865	554,291	1875	3,462,382
1836	352,862	1846	288,112	1856	do	1866	691,820	1876	4,853,461
1837	344,147	1847	255,476	1857	do	1867	998,905	1877	6,816,971
1838	340,554	1848	327,802	1858	do	1868	735,734	1878	9,931,644
1839	358,357	1849	328,280	1859	do	1869	1,685,229	1879	12,541,646
1840	337,010	1850	No report	1860	do	1870	1,704,465	1880, to June 1	3,586,059
1841	326,695	1851	do	1861	do	1871	1,375,981		

EXPORTED FROM BAKU IN POODS OF 36 POUNDS.

	1875.	1876.	1877.	1878.	1879.	1880 to June 1.
Crude oil	323,851	323,561	177,983	281,423	436,673	61,902
Refined oil	1,990,041	3,325,233	4,594,766	6,254,920	6,562,140	1,484,374
Refuse	1,131,725	1,275,321	2,038,899	3,382,859	5,528,208	20,016,270
Oil and grease	1,077	1,095		306	409	23,503
Asphalt	4,586	13,100	723	9,300	10,491	
Benzine, etc	11,102	5,151	4,600	3,130		

TABLE XII.—IMPORTS OF AMERICAN PETROLEUM (REFINED) INTO JAPAN.

Year ending June 30—.	Gallons.	Dollars.	Years.	Gallons.	Dollars.	Years.	Gallons.	Dollars.
1872*	41,470	21,150	1875	2,826,636	573,671	1878	5,524,604	1,115,162
1873	1,000,959	330,598	1876	3,151,639	520,387	1879	17,721,645	2,557,509
1874	1,291,180	306,723	1877	3,304,926	599,966	1880	17,923,499	1,803,555
						Total	**52,745,088**	**7,807,571**

* First importation.

CHAPTER VIII.—THE BIBLIOGRAPHY OF BITUMEN AND ITS RELATED SUBJECTS.

An examination of the literature of petroleum shows that the subject is properly treated as a portion of the general subject "Bitumen". It is impossible to separate it from asphalt, maltha or mineral tar, rock oil, earth oil (German *Erdöl*), naphtha, coal oil, and paraffine. These several subjects are also treated as pertaining to history, geology, chemistry, technology, commerce, and statistics, and often in such a manner as to render a separation impossible. In ascertaining what articles have appeared in different periodicals, the indices have been searched for "Asphaltum", "Bitumen", "Gas", "Hydrocarbons", "Maltha", "Mineral tar", "Naphtha", "Oils", "Paraffine", and "Petroleum", with their equivalents in other languages.

Two attempts have previously been made to prepare lists of books and of periodical articles relating to this subject. Professor Paul Schweitzer, of the University of Missouri, published his list, in 1879, in connection with his pamphlet on petroleum. Another was prepared in the East Indies, in 1875, by Mr. Benjamin S. Lyman, but was not published. This latter list of titles has been placed in my hands, and has been incorporated with my own work, the 175 titles being distinguished by printing the authors' names preceded by an asterisk. Professor Schweitzer's list was not prepared in such a manner as to admit of such incorporation, but for the most part his titles will be found in the present list.

In submitting this list of titles to my fellow-workers in this field, it is not claimed that it is either complete or free from error. Mr. Lyman's titles were transferred, and many of the others are quoted without being verified; but, so far as has been possible in the time at my command, the work has been proved correct. Only titles to articles of exceptional value have been inserted when the authors are unknown. This, of course, excludes a large number of editorial notices, both good and bad, that are found in reputable scientific journals, as well as in newspapers. I have endeavored, however, to include what is of material value.

So far as I have been able to do it, I have inserted the title to a work in the language in which it was originally written, and I have also endeavored to insert the reference to the work in which the article first appeared, as the first in the list of references. I am aware, however, that in a few instances I have not met the original articles, and that the titles appear translated into other languages. The material was all collected in the course of the preparation of the report, and only required the labor of arrangement to put it in this form.

ABBREVIATIONS.

A. C. et P.	Annales de Chimie et de Physique.
A. C. u. P.	Annalen der Chemie und Pharmacie.
A. der P.	Archiv der Pharmacie.
A. J. Ph.	American Journal of Pharmacy.
A. J. S.	American Journal of Science and Arts (Silliman's Journal).
Am. C.	American Chemist.
Am. J. G. L.	American Journal of Gaslighting.
An. G. C.	Annales du Génie Civil.
An. M.	Annales des Mines.
A. of P.	Annals of Philosophy.
A. S. D.	Annual of Scientific Discovery.
B. D. C. G.	Berichte der Deutschen Chemischen Gesellschaft zu Berlin.
B. I. u. Gbl.	Bayerisches Industrie- u. Gewerbeblatt.
B. N. A. W. M.	Bulletin of the National Association of Wool Manufacturers.
B. S. C. P.	Bulletin de la Société Chimique de Paris.
B. S. d'E.	Bulletin de la Société d'Encouragement.
B. S. G. F.	Bulletin de la Société Géologique de France.
B. u. H. J.	Leobener Berg- und Hütten-Jahrbuch.
B. u. H. Z.	Berg- und Hütten- Zeitung.
Bull. A. I. St. P.	Bulletin de l'Académie Impériale des Sciences de Saint-Péters bourg.
C. Cbl.	Chemisches Centralblatt.
C. Ind. Z.	Chemische Industrie-Zeitung.
C. N.	London Chemical News.
C. Nat.	Canadian Naturalist.
C. R.	Comptes-Rendus des Séances de l'Académie Française.
C. Z.	Chemische Zeitung.
D. Ill. G. Z.	Deutsche Illustr. Gewerbe-Zeitung.
D. Ind. Z.	Deutsche Industrie-Zeitung.
Dingler.	Dingler's Polytechnisches Journal.
E. M. W. S.	English Mechanic and World of Science.
Eng.	Engineering.
F. Gztg.	Fürther Gewerbezeitung.
G. Ind.	Génie Industriel.
H. Gbl.	Hessisches Gewerbeblatt.
Hübner's Z.	Hübner's Zeitschrift für die Paraffin-, Mineralöl-, und Braunkohlen-Industrie.
Ind. B.	Industrie-Blätter.
Int. Obs.	Intellectual Observer.
J. A. S. B.	Journal of the Asiatic Society of Bengal.
J. C. S.	Journal Chemical Society of London.
J. F. I.	Journal of the Franklin Institute.
J. f. P. C.	Journal für Praktische Chemie (Erdmann's Journal).
J. G. B.	Journal für Gasbeleuchtung.
J. K. K. G. R.	Jahrbuch der K. K. Geologischen Reichsanstalt.
J. S. A.	Journal of the Society of Arts.
L'A. S. et I.	L'Année Scientifique et Industrielle.
Le Tech.	Le Technologiste.
L. J. G. L.	London Journal of Gas Lighting.
L. u. B. J.	Leonhardt und Bronn Jahrbuch.
Mem. A. A.	Memoirs American Academy of Arts and Sciences, Boston.
M. P. L. S.	Proceedings of the Manchester Philosophical and Literary Society.
M. Sci.	Moniteur Scientifique.
N. E. P. J.	New Edinburgh Philosophical Journal.
N. J. Ph.	Neues Jahrbuch für Pharmacie.
N. Z. R. I.	Neue Zeitschrift für Rübenzucker Industrie.
Oest. Z. f. B. u. H.	Oesterreich. Zeitschrift für Berg- und Hüttenwesen.
P. A. A. A. S.	Proceedings of the American Association for the Advancement of Science.
P. A. Ph. A.	Proceedings of the American Pharmaceutical Association.
P. A. P. S.	Proceedings of the American Philosophical Society, Philadelphia.
P. B. A. A. S.	Proceedings of the British Association for the Advancement of Science.
P. C. A. S.	Proceedings of the California Academy of Science.
P. G. S.	Proceedings of the Geological Society, London.
Pharm. Chl.	Pharmaceutisches Centralblatt.
Ph. J.	Pharmaceutical Journal, London.
P. I. C. E.	Proceedings of the Institution of Civil Engineers, London.
P. J.	Philosophical Journal.
P. M.	Philosophical Magazine.
Pog. An.	Poggendorf's Annalen der Physik.
Poly. Cbl.	Polytechnisches Centralblatt.
Poly. Nbl.	Polytechnisches Notizblatt.
P. R. I.	Proceedings of the Royal Institution.
P. R. S.	Proceedings of the Royal Society.
P. S. M.	Popular Science Monthly.
P. T.	Philosophical Transactions of the Royal Society.
Q. J. G. S.	Quarterly Journal of the Geological Society of London.
R. C. A.	Repertoire de Chimie Appliquée.
R. I.	Revue Industrielle.
R. U. M.	Revue Universelle des Mines.
Sci. Am.	Scientific American.
S. M. & Sci. P.	San Francisco Mining and Scientific Press.
S. P. Z.	Schweiz. Polytechnische Zeitschrift.
T. A. I. M. E.	Transactions of the American Institute of Mining Engineers.
T. A. Ph. A.	Transactions of the American Pharmaceutical Association.
T. G. S.	Transactions of the Geological Society, London.
T. P. S. E.	Transactions of the Pharmaceutical Society (English).
Trans. Am. P. S.	Transactions of the American Philosophical Society.
Trans. R. S.	Transactions of the Royal Society.
W. B.	Wagner's Berichte.
Z. A. C.	Zeitschrift für Analytische Chemie.
Z. A. O. A.	Zeitschrift des Allgemeinen Oesterreich. Apotheker-Vereins.
Z. C.	Zeitschrift für Chemie.

The few abbreviations of the titles to other journals are extended so as to need no reference.

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B. C.			
Circa 450	*Ctesias	Gas in Karamania	Fragment (ed. Bachr.), cap. x, p. 250.
Circa 450	*Herodotus	lib. iv, 195	Translated into French in B. S. G. F., xxv, 62.
Circa 350	*Aristotle	Albanian bitumen; in De mirabilibus auscultationibus, chap. cxxvii (Ed. de F. Didot, 1857).	Translated into French in B. S. G. F., xxv, 25.
Circa 25	*Diodorus Siculus	Dead Sea bitumen; t. i, l. ii, cap. xxix. Hist. Univers., t. vi, l. xix, cap. xxv.	Translated into French in B. S. G. F., xxiv, 14.
Circa 25	*Strabo	vi, 763; xvi, c. 2; c. 12; French translation, 1, xiv, p. 665, Casab.	Translated into French in B. S. G. F., xxiv, 13. Geographie, 1812, iii, 8. B. S. G. F., xxv, 20.
Circa 25	Vitruvius	lib. vii, cap. 3	Translated into French in B. S. G. F., xxv, 5[illegible]
A. D.			
Circa 25	*Seneca		Epist. 79, § 3. Ed. Ruhkopf.
Circa 50	*Pliny	N. H., lib. ii, § 106; vii, 13; lib. xxxv	Quoted in B. S. G. F., xxv, 21.
Circa 66	*Plutarch	Albanian bitumen; Life of Sylla	Quoted in B. S. G. F., xxv, 22. Sir Thomas North's translation, ed. 1631, p. 702.
Circa 80	*Tacitus		Hist., v, 6.
Circa 100	*Josephus		H. J., iv, 8, 4.
Circa 120	*Aelian	Albanian bitumen; Variæ historiæ, lib. xiii, § 16	Quoted in B. S. G. F., xxv, 21.
Circa 200	*Dion Cassius	Albanian bitumen; Roman. Histor., l. xli	Quoted in B. S. G. F., xxv, 22.
Circa 225	*Philostratus		Appollonius of Tyana, I, 17.
Circa 1300	*Polo, Marco	Book I, ch. iii	(Vol. i, p. 46, of Col. Yule's edition, 1871.) See also note in Marsden's edition.
Circa 1325	*Abulfeda	Dead sea (asphalt)	t. ii, 1re partie, p. 48. (Trad. de Rainaud et de Slane).
Circa 1360	*Mandeville.		

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1638	*Herbert, T.	Baku oil	"Some Years' Travels," 1638.
1672	*Fryer, J., M. D	Asphalt	New account of East India and Persia, nine years' travels, 1672–1681, p. 318.
1697	*Herbelot, D	Fountains of Hit	Bibliothèque Orientale, *sub voce*: Hit, 1697.
1712	*Kæmpfer	Baku	Amœnitates Exoticæ, 1712, p. 274, etc.
1721	Eirinis d'Erynys	Dissertation sur l'asphalte ou ciment naturel, découvert depuis quelques années au Val de Travers, etc.	Paris, 1721.
1734	*Hanway, Jonas	Baku oil	1734.
Circa 1746	*Bianconi (G. L.?)	Mud volcanoes	Storia naturale dei terreni ardenti, 1746(?), p. 24.
1750	Hughes, Griffith	Natural history of Barbadoes	London, 1750, p. 50.
1758	Gumilla	Trinidad bitumen	Description of Orinoco, published originally in Spanish and translated into French.
1772	Kalm, Peter	Travels in North America, with map locating springs.	Originally published in Swedish, but has been translated into English.
1782	Müller	Beschreibung der in Tirol üblichen Art das Steinöl zu bereiten.	Abhandlungen einer Privatgesellschaft in Böhmen, v, 333.
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1789	......	Notice of oil springs in Pennsylvania	Mass. Magazine, i, 416; Am. C., iii, 174.
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1800	*Turner, S	Chittagong oil gas	Account of an embassy to the court of the Teshoo Lama in Thibet, 1800.
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1811	Bright, Richard	On the strata in the neighborhood of Bristol	T. G. S. (1), ii, 199.
1811	Nugent, Nicholas	Account of the Pitch lake of the island of Trinidad	T. G. S. (1), i, 63.
1812	*Morier	Baku oil	Journey through Persia, Armenia, etc., 1812.
1813	Kinnier, J. M	Baku oil, etc	Geographical Memoir of the Persian Empire, 4°, 1813.
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1820	*Beaufort	Gas in Karamania	Survey of the coast of Karamania, 1820, p. 24.
1820	Buchner	Paraffin	Repertor. für Pharmacie, 1820, p. 290.
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1820	Saussure, Theo. de	Paraffine	Bibliothèque Universelle, iv, 116.
1820	Thomson, Dr	Properties of native naphtha	Journal of Science, ix, 408.
1821	Edited from travels of Foster, Hanway, Reiberstein, Cook, Kinnier, and Hiram Cox, and from a paper by J. J. Virey.	Naphtha springs of Baku and Pegu	P. J., v, 22, 26; Jour. de Pharmacie, vi, 209.
1822	*Burckhardt	Dead Sea asphalt	Travels in Syria and Palestine, 1822.
1822	Note by editor	Oil, Barbadoes tar and munjack	A. J. S. (1), v, 406.
1823	Knox, George	Bitumen and other volatile ingredients in stones	P. T., 1823; A. J. S. (1), xii, 147; P. J., ix, 403; A. C. et P. (2), xxv, 178, 180.
1824	*Keppel, G	Baku oil	Journey from India to England, 1824.
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1826	*Crawfurd, John	Journal of an embassy to the court of Ava	London, 2 vols., 8°, 1834, i, 93; ii, 23, 178, 206, 238.
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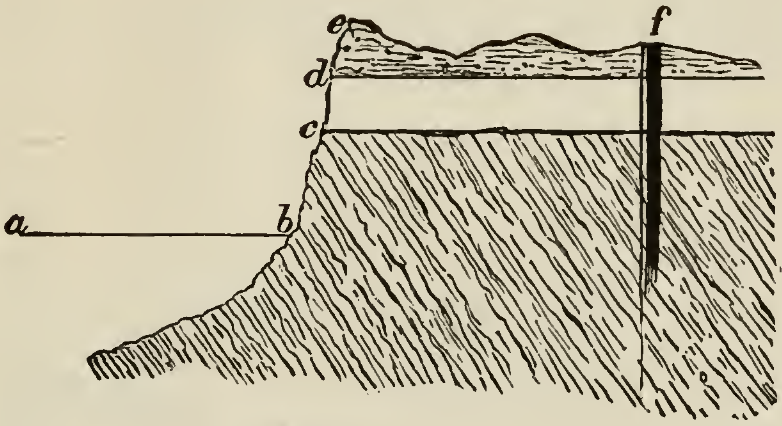
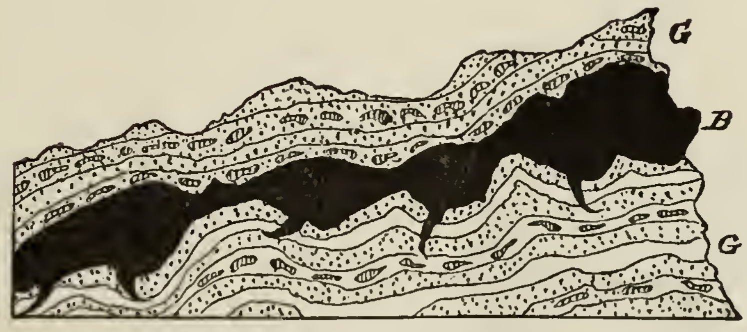


a, *b*, Sea-level.
b, *c*, Bituminous shale.
c, *d*, Unstratified sand saturated with bitumen
d, *e*, Soil.
f, Well, recently commenced (1866).

[Fig. 1—page 21.]

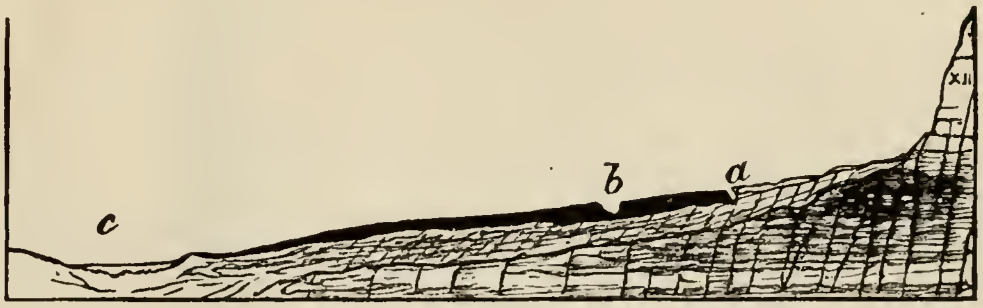
Section of bituminous rocks on Bigg's ranch, Santa Barbara Co., California.



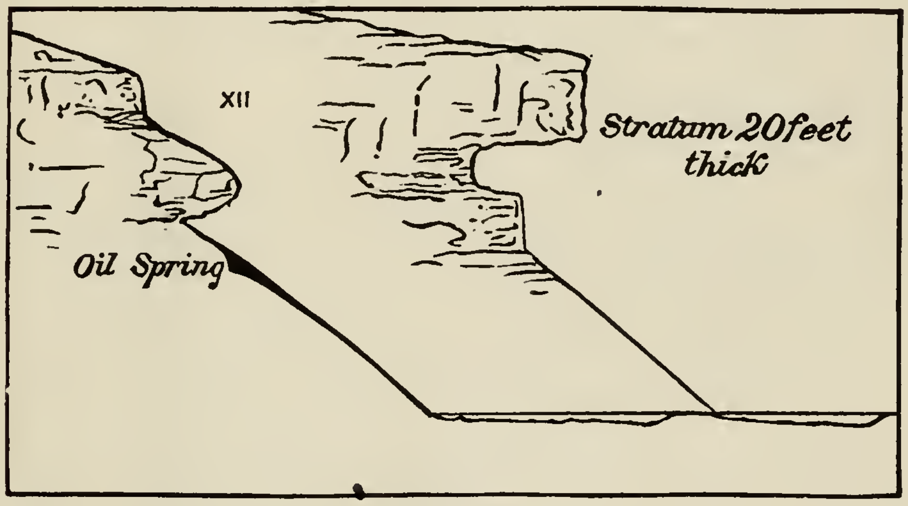
B, Solid bitumen. G, Sandstones and conglomerates.

[Fig. 2—page 32.]

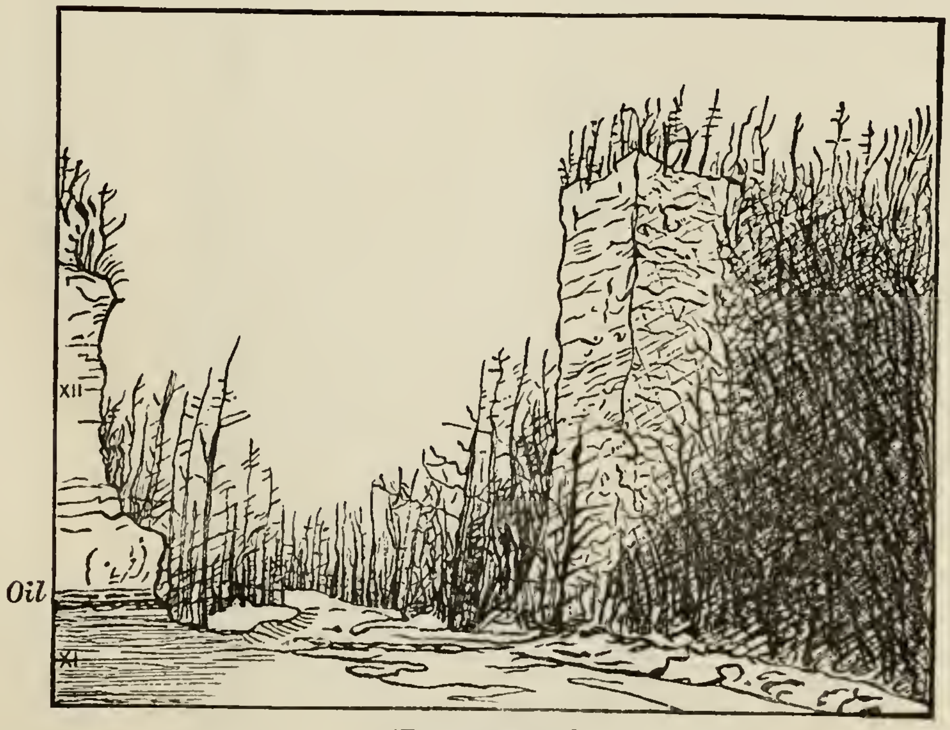
Bitumen at Selenitza, Albania.



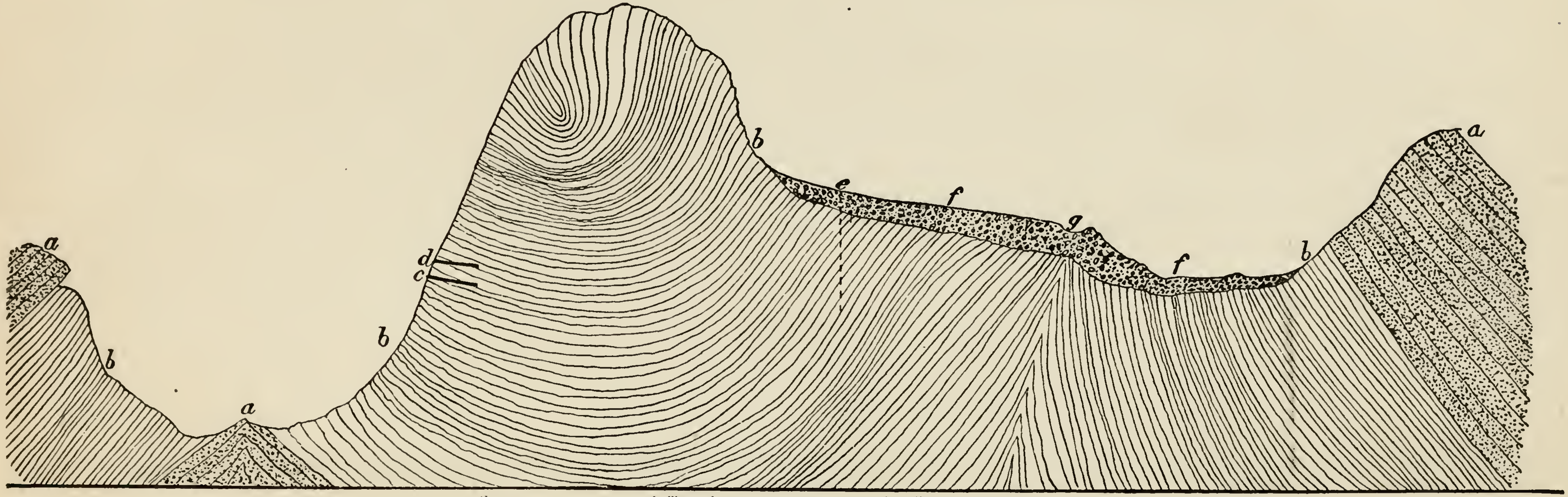
[Fig. 3—page 63.]
Old oil springs, Paint creek, Johnson Co., Ky.



[Fig. 4—page 63.]
Section on Little Paint creek, Johnson Co., Ky.



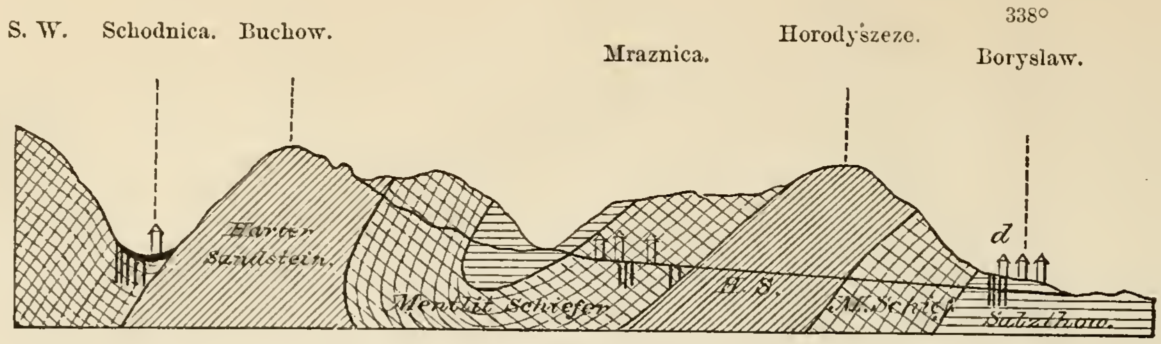
[Fig. 5—page 63.]
Crows' Nest, on Paint creek, Johnson Co., Ky.



a, Sandstone.
b, Shale.
c d, Tunnels.
e, Well on Ojai ranch.
f, Soil.
g, Big spring on Ojai ranch.

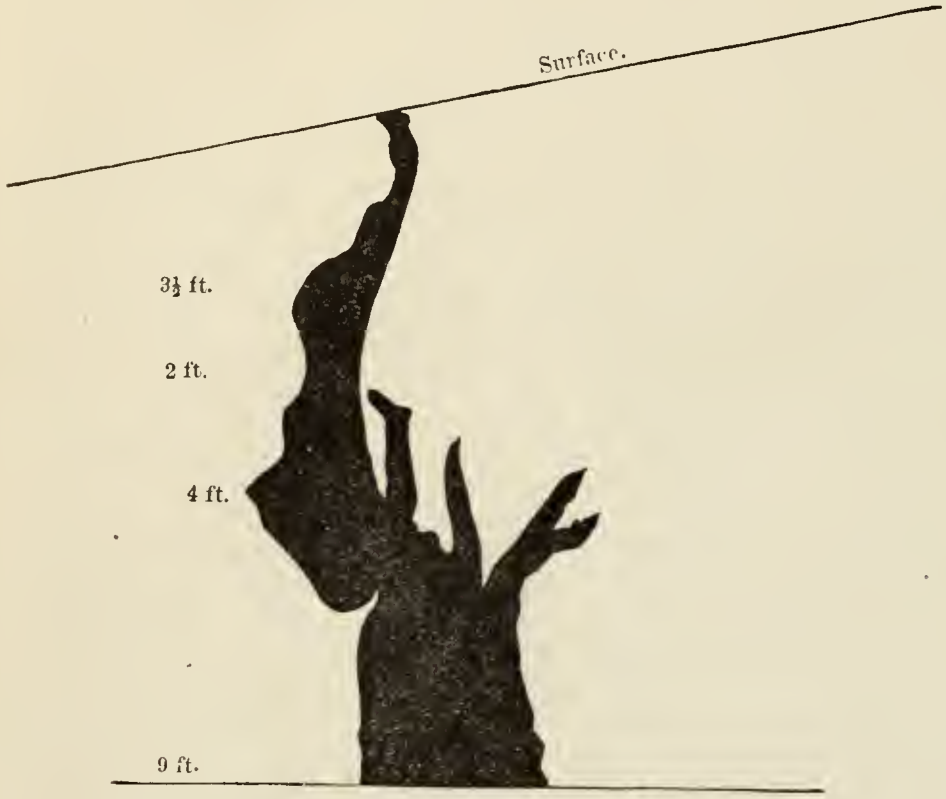
[Fig. 6—page 68.]

Section through Sulphur mountain and Ojai plateau, Ventura county, California.



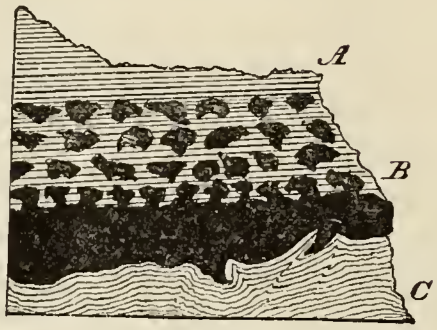
[FIG. 7—page 72.]

Section from Boryslaw to Schodnica, East Galicia.



[FIG. 8—page 72.]

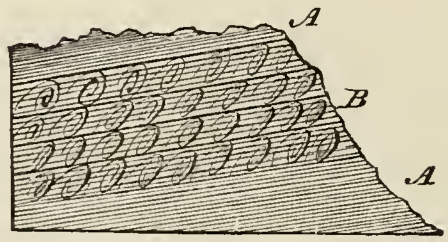
Section of vein of asphaltum near Havana, Cuba.



A, Slates. B, Asphalt. C, Breccia.

[FIG. 9—page 73.]

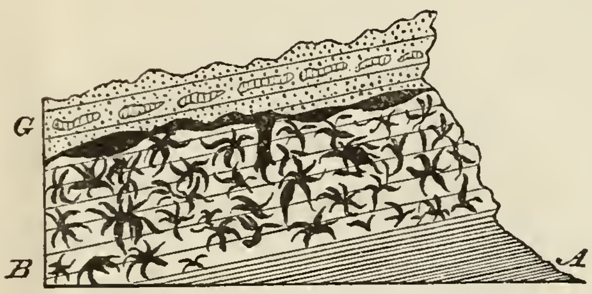
Bitumen in Albania.



A, Slates. B, Pisolithic bitumen.

[FIG. 10—page 73.]

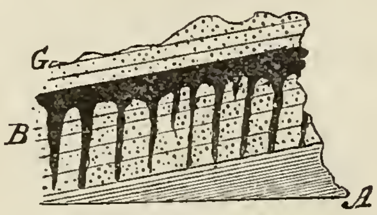
Bitumen in Albania.



A, Slates. B, Reticulated bitumen.
G, Sandstones and conglomerates.

[FIG. 11—page 73.]

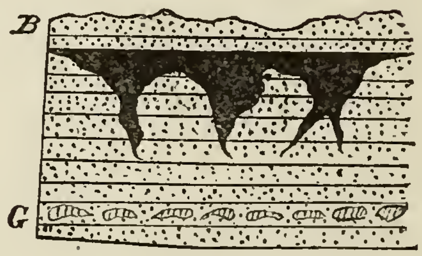
Bitumen in Albania.



A, Slates. B, Bitumen.
G, Sandstones.

[FIG. 12—page 73.]

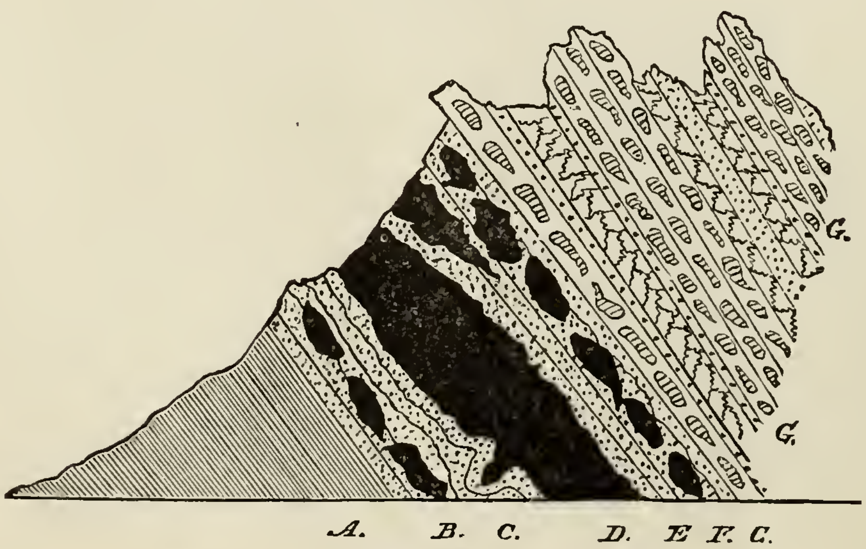
Bitumen in Albania.



B, Bitumen.
G, Conglomerate.

[FIG. 13—page 73.]

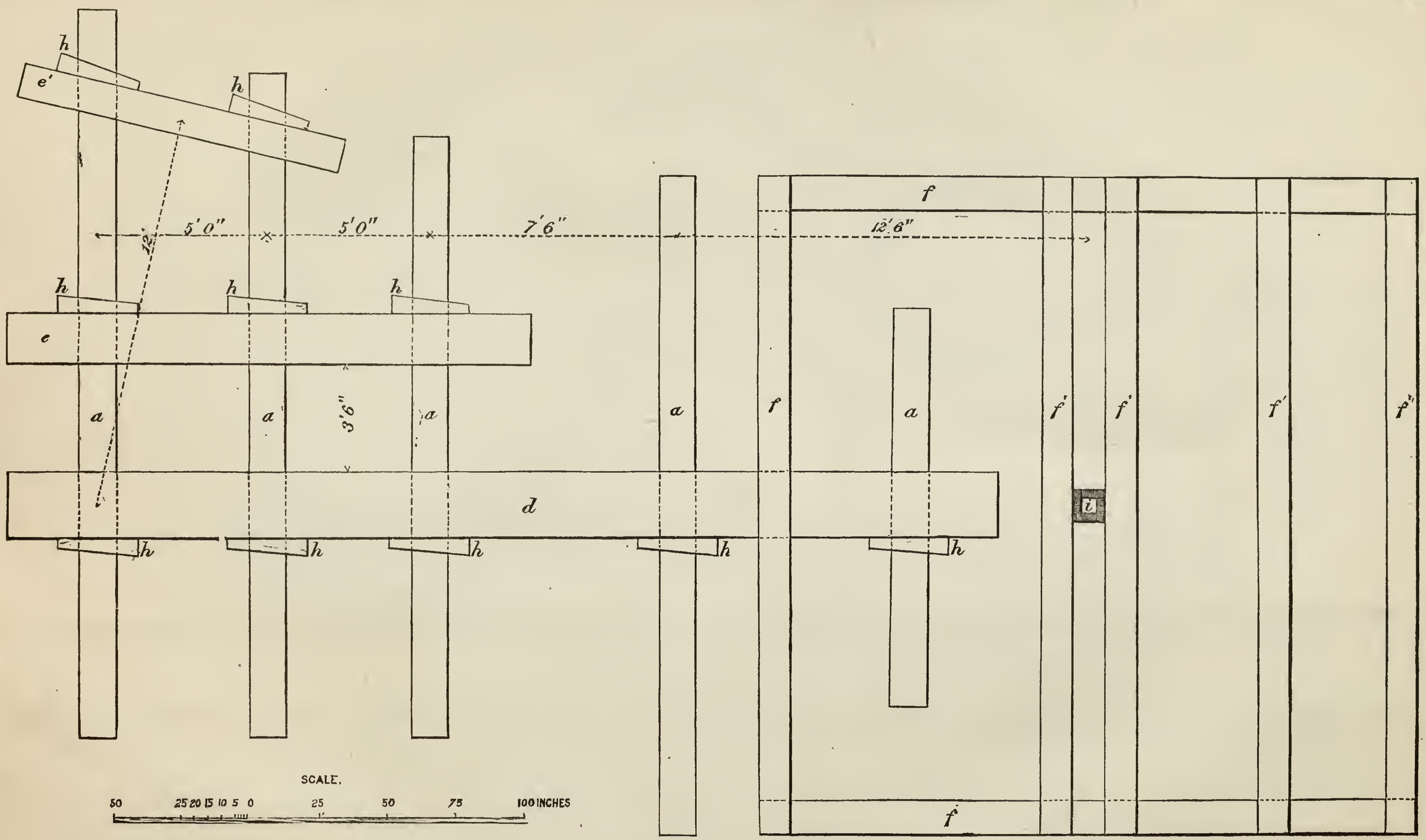
Bitumen in Albania.



[FIG. 14—page 73.]

1. A, Slates, 90 meters.
2. B, Conglomerate, with balls of bitumen, 3 meters.
3. C, Yellow sandstone, with bivalves, 2 meters.
4. D, The great mass of bitumen, 45 meters.
5. E, Yellow sandstone with cardium edule, 2.5 meters.
6. F, Alternating sandstones and conglomerates, with balls of bitumen, 3.6 meters.
7. G, Conglomerates and sandstones, 60 meters.

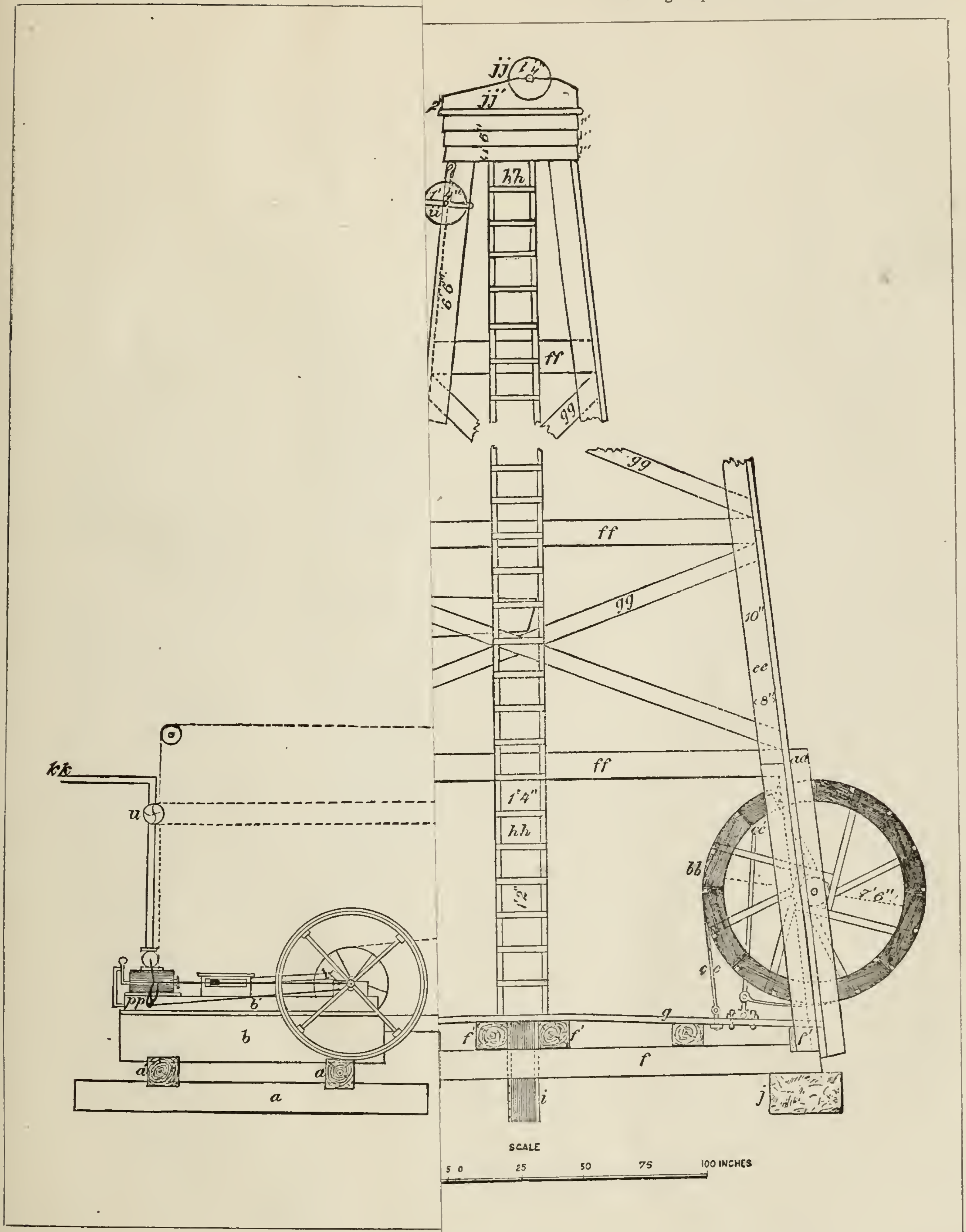
Bitumen in Albania.



[Fig. 15—page 79.]

Foundation timbers for rig.

Plate XIV.


jj
jj'
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ii
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10"
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8"
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1'4"
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12"
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g
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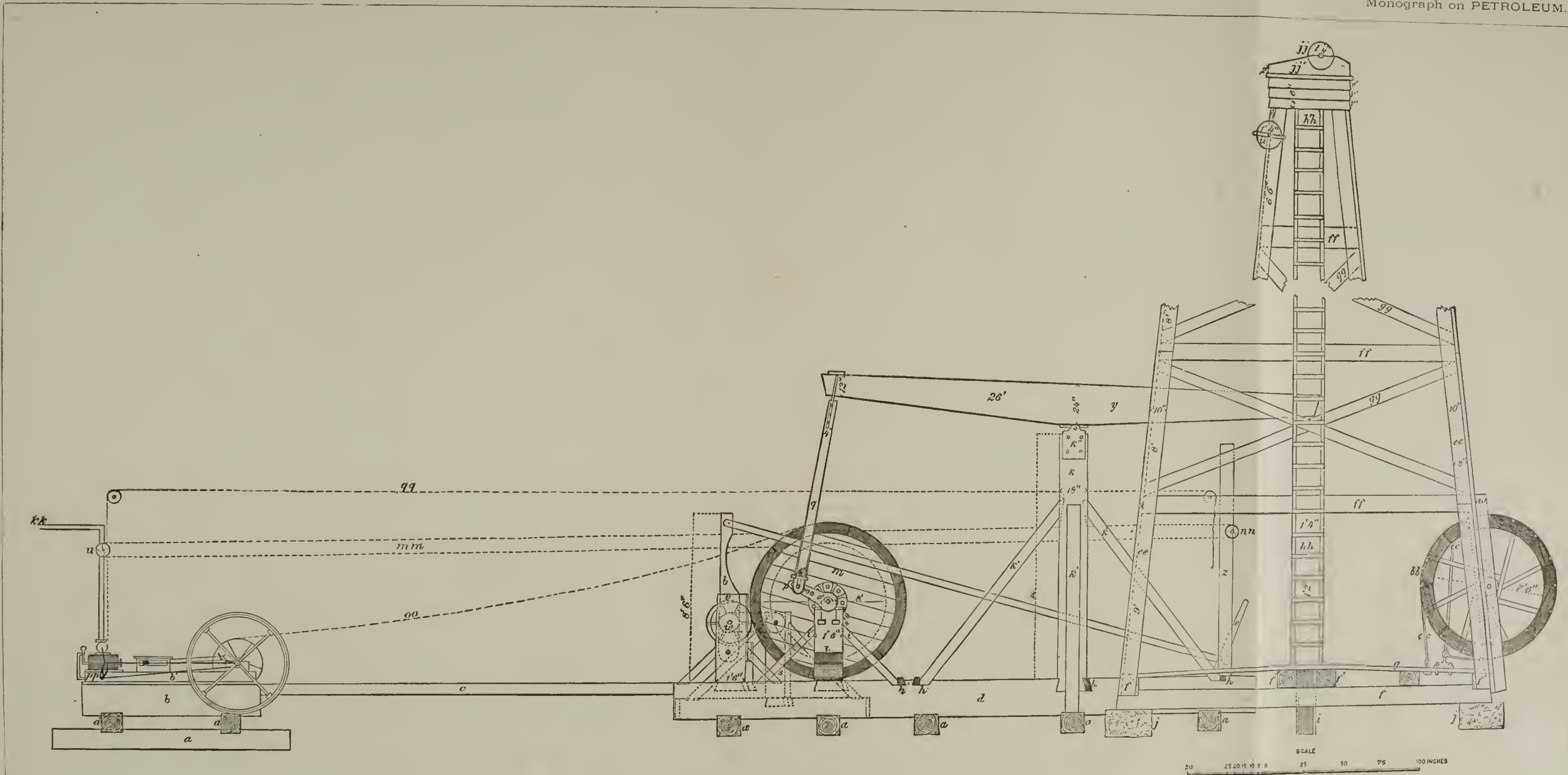
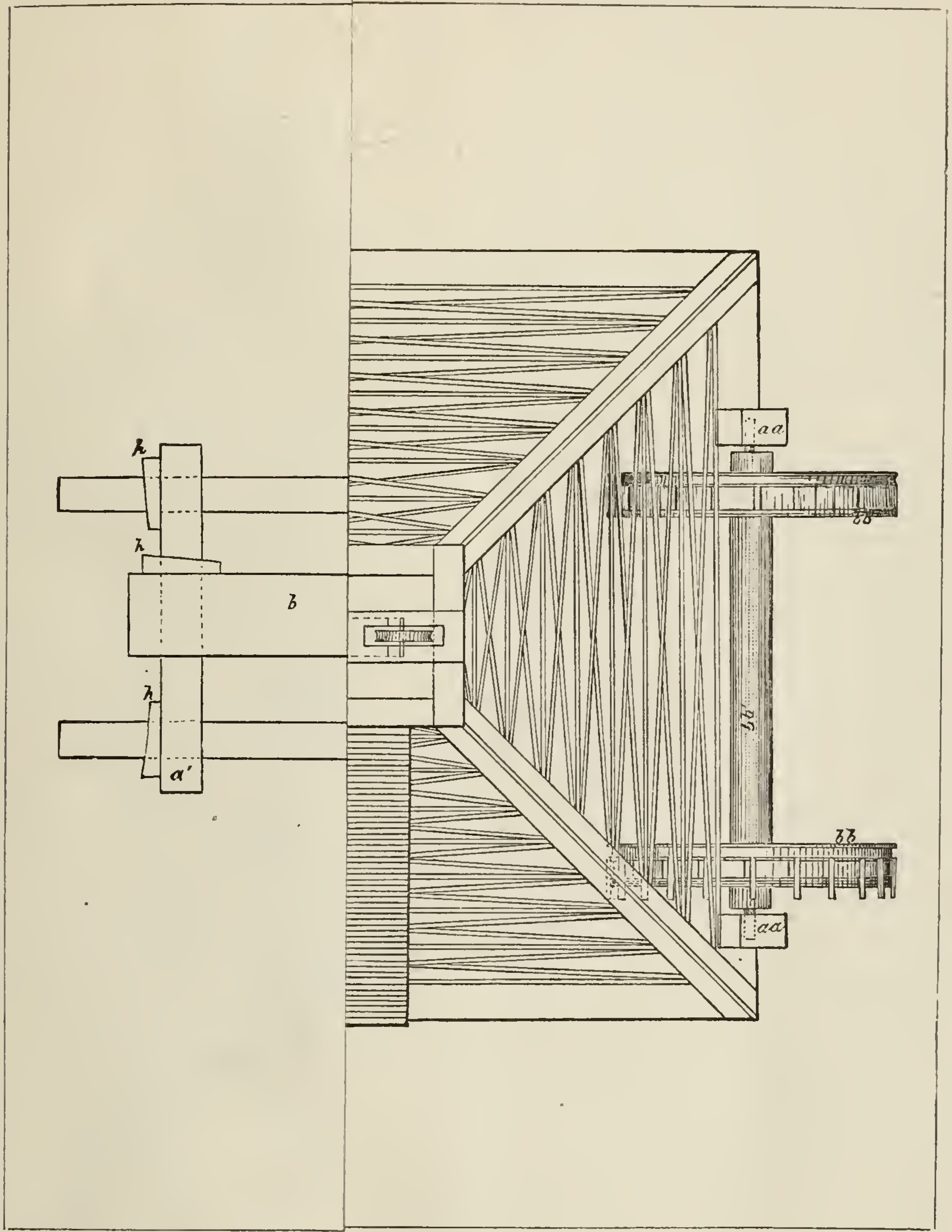
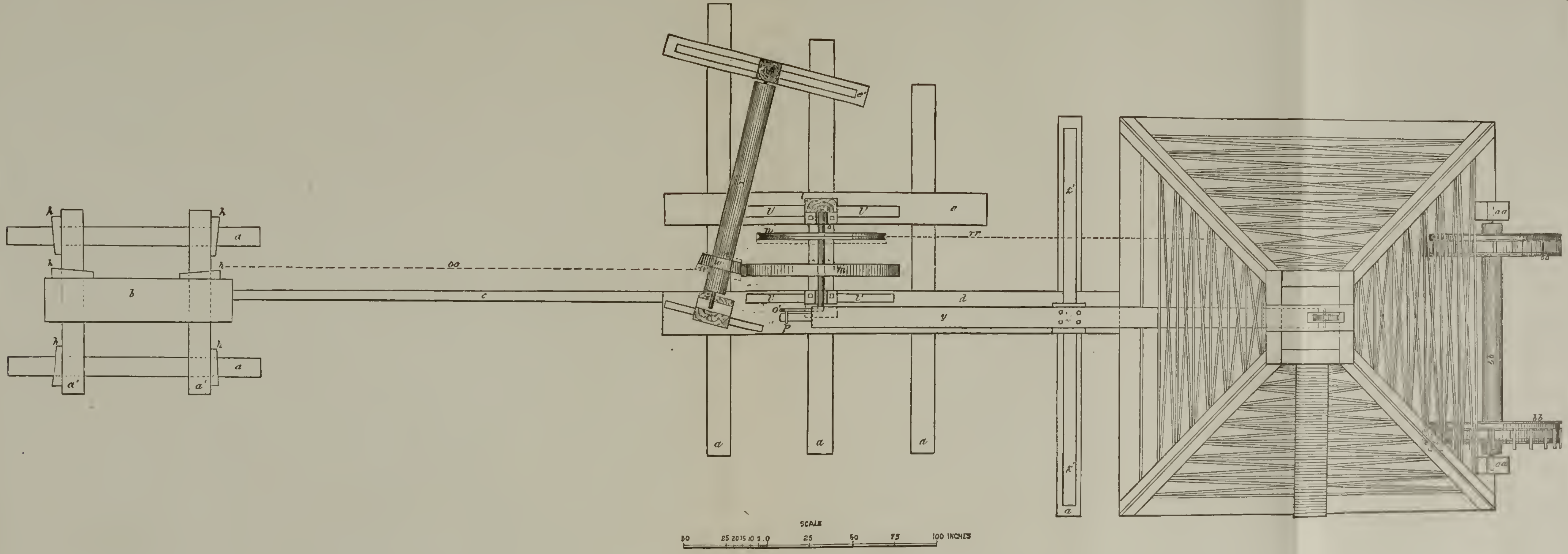
f'
f
f'
i
j
SCALE
5 0
25
50
75
100 INCHES



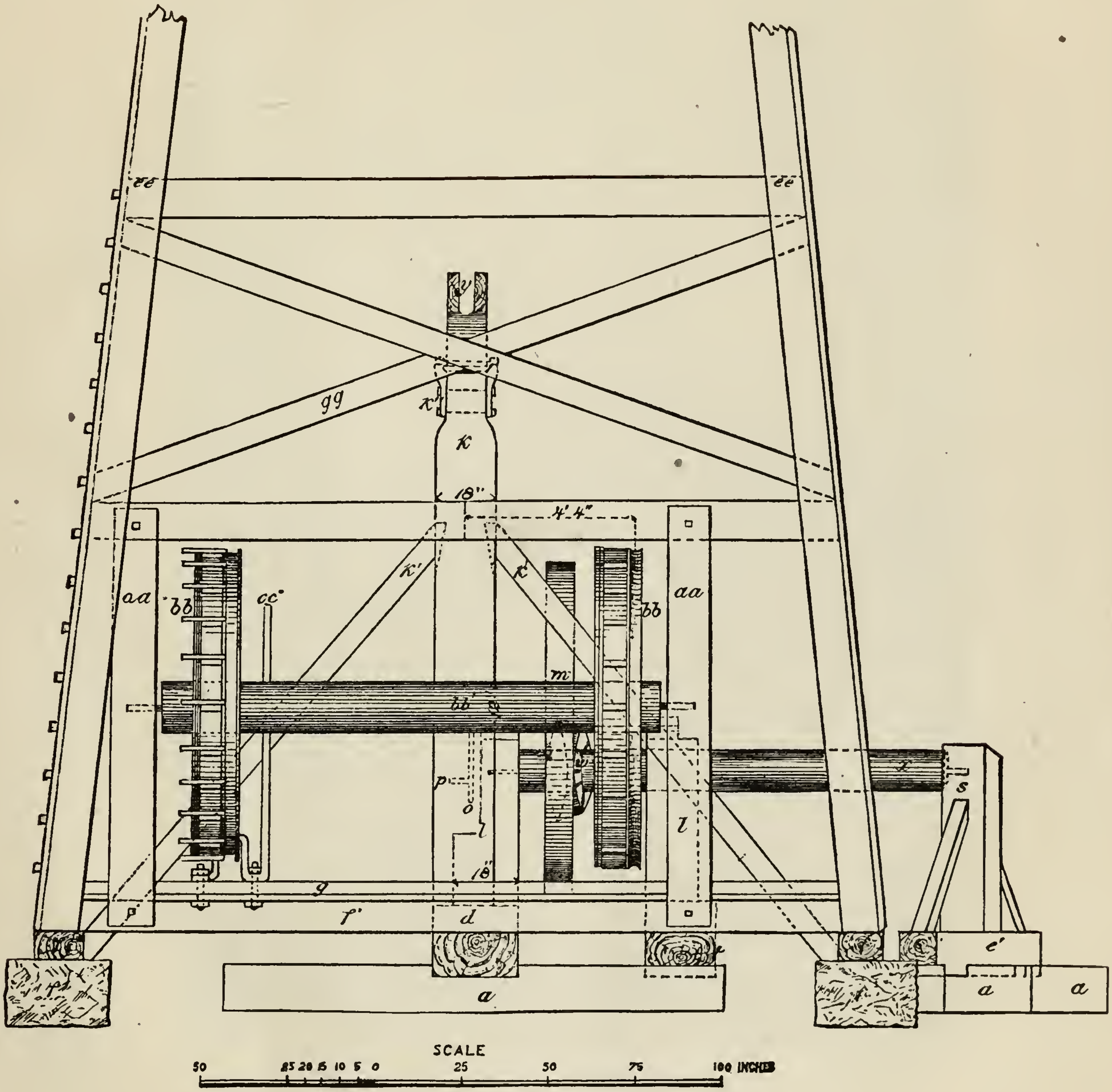
[Fig. 16—page 80.]
Side elevation of derrick and engine


h
h
b
h
a'
aa
bb
bb'
bb
aa



[Fig. 17—page 80.]

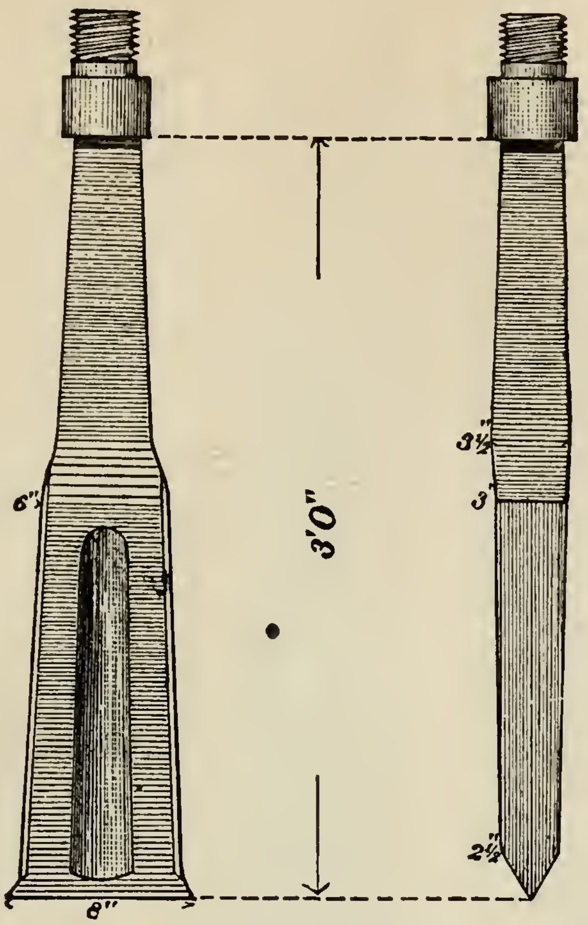
Horizontal projection of derrick and engine.



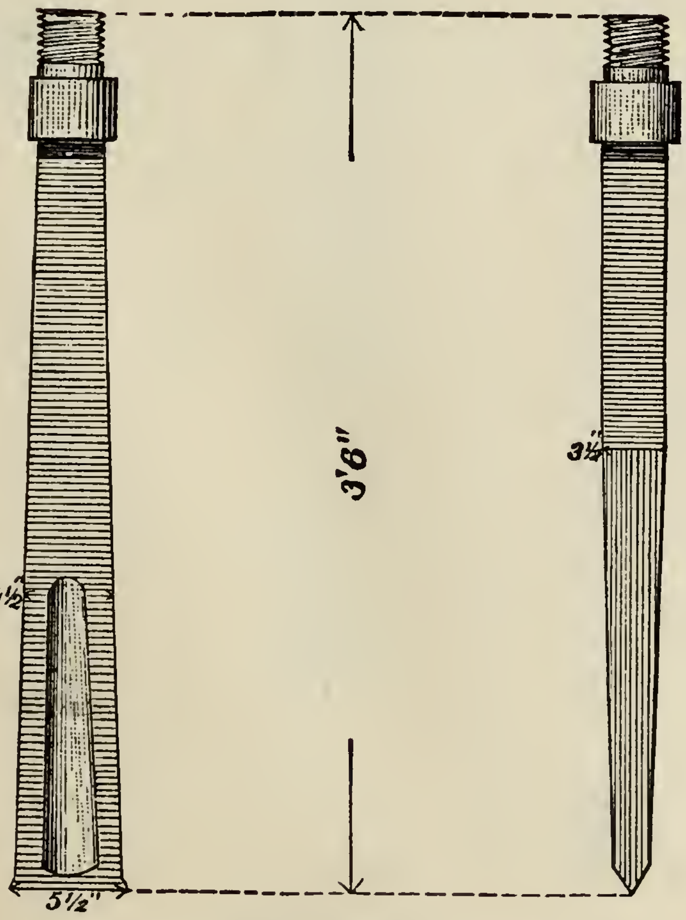
[Fig. 18—page 80.]

End elevation of derrick.

[Fig. 19—page 81.]
Inside view of derrick at night, showing use of temper-screw and derrick light.



[FIG. 20—page 81.]
Eight-inch bit, 1-12 natural size.

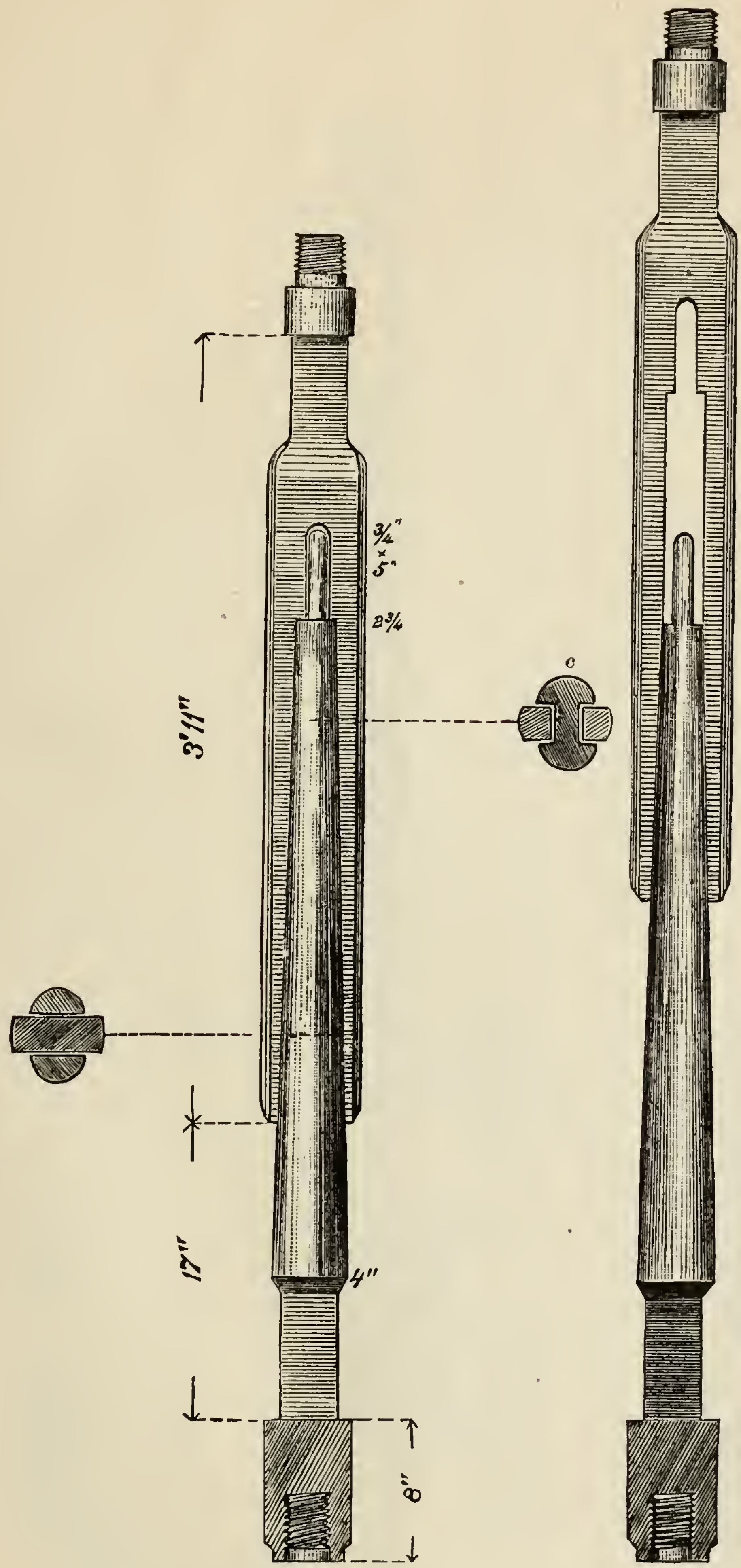


[FIG. 21—page 81.]
Five-and-one-half-inch bit, 1-12 natural size.

[FIG. 22—page 81.]
Auger stem.

[FIG. 24—page 81.]
Sinker bar.

1-12 natural size.



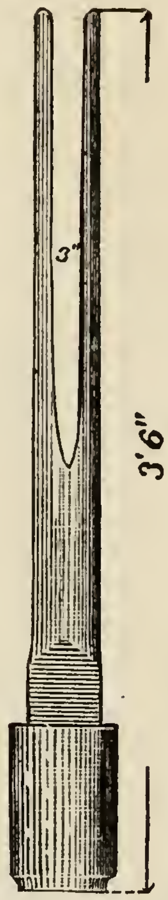
a
Closed.

b
Open.

c and *d*, cross-sections

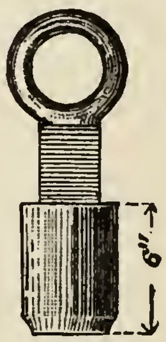
[FIG. 23—page 81.]

Jars, 1-12 natural size.



[FIG. 25—page 81.]

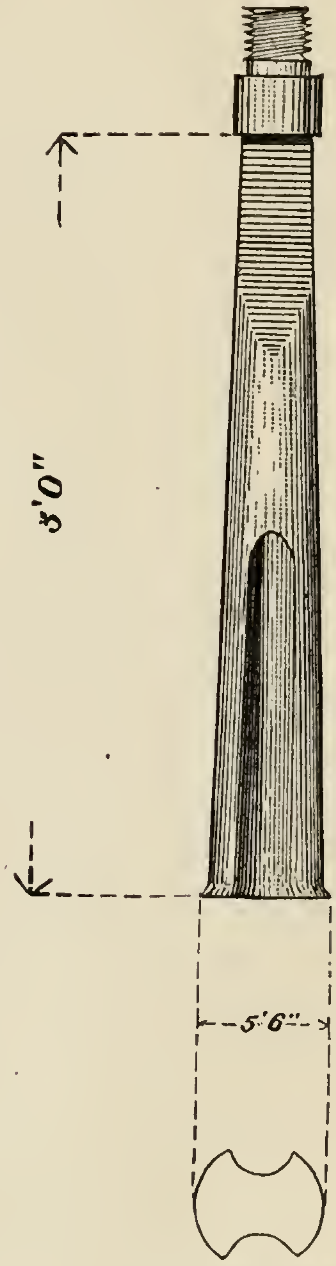
Rope socket, 1-12 natural size.



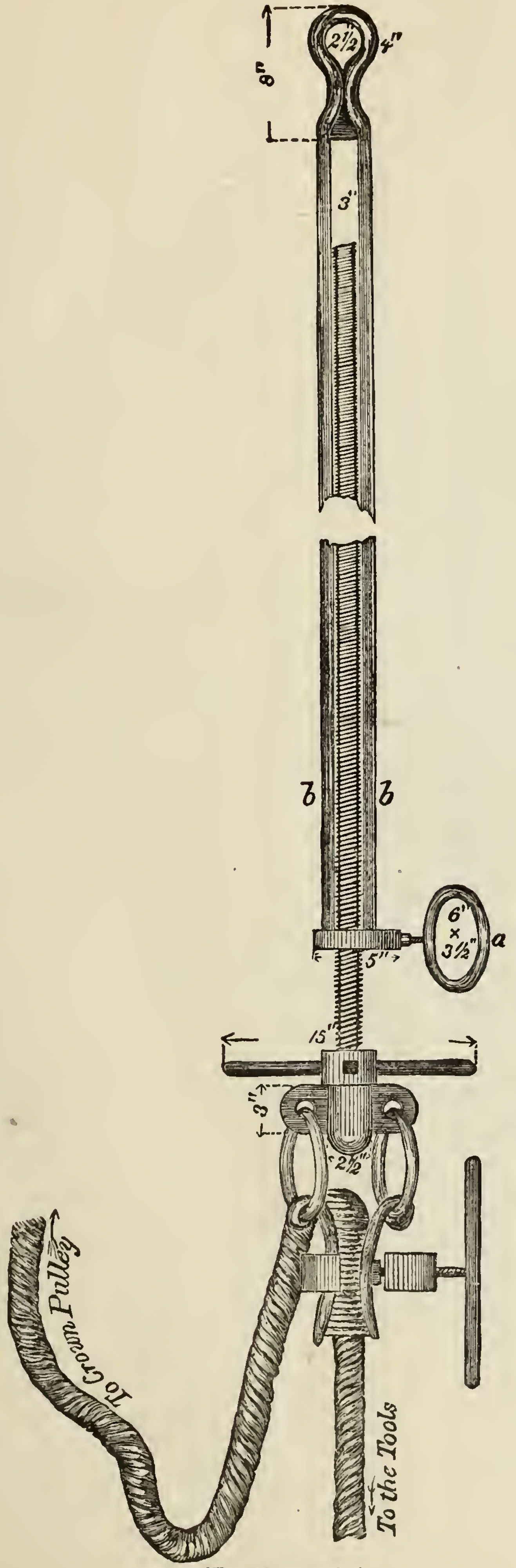
[FIG. 27—page 81.]

Ring socket, 1-12 natural size.

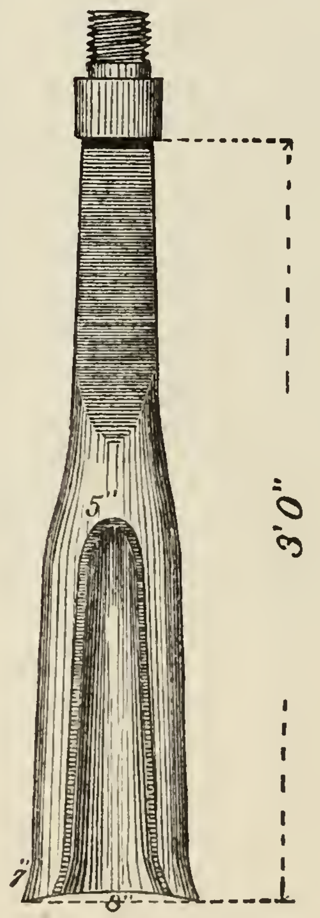
[Fig. 28—page 81.]
Wrench, 1-12 natural size.



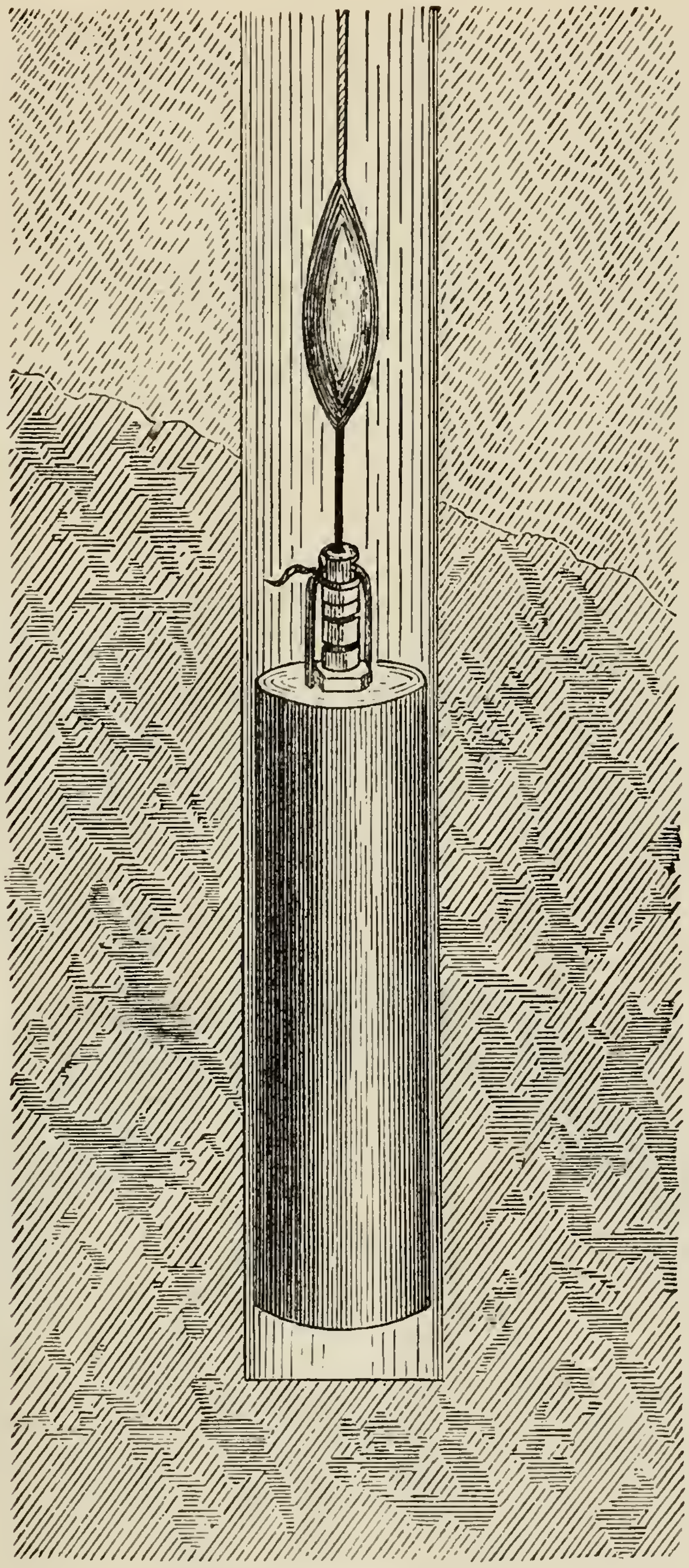
[Fig. 29—page 81.]
Five-and-one-half-inch reamer, 1-12 natural size.



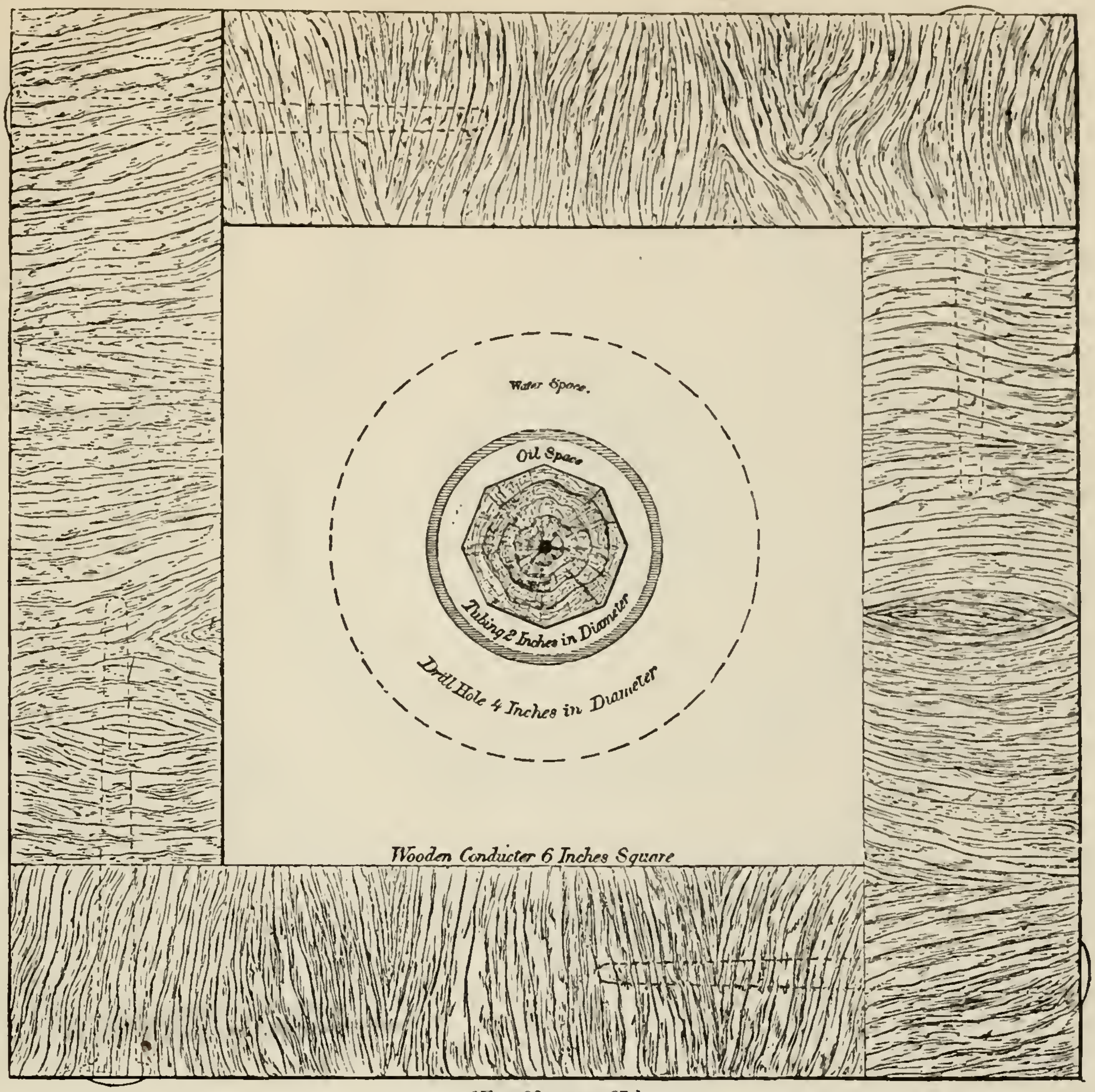
[Fig. 26—page 81.]
Temper-screw.



[Fig. 30—page 81.]
Eight-inch reamer.

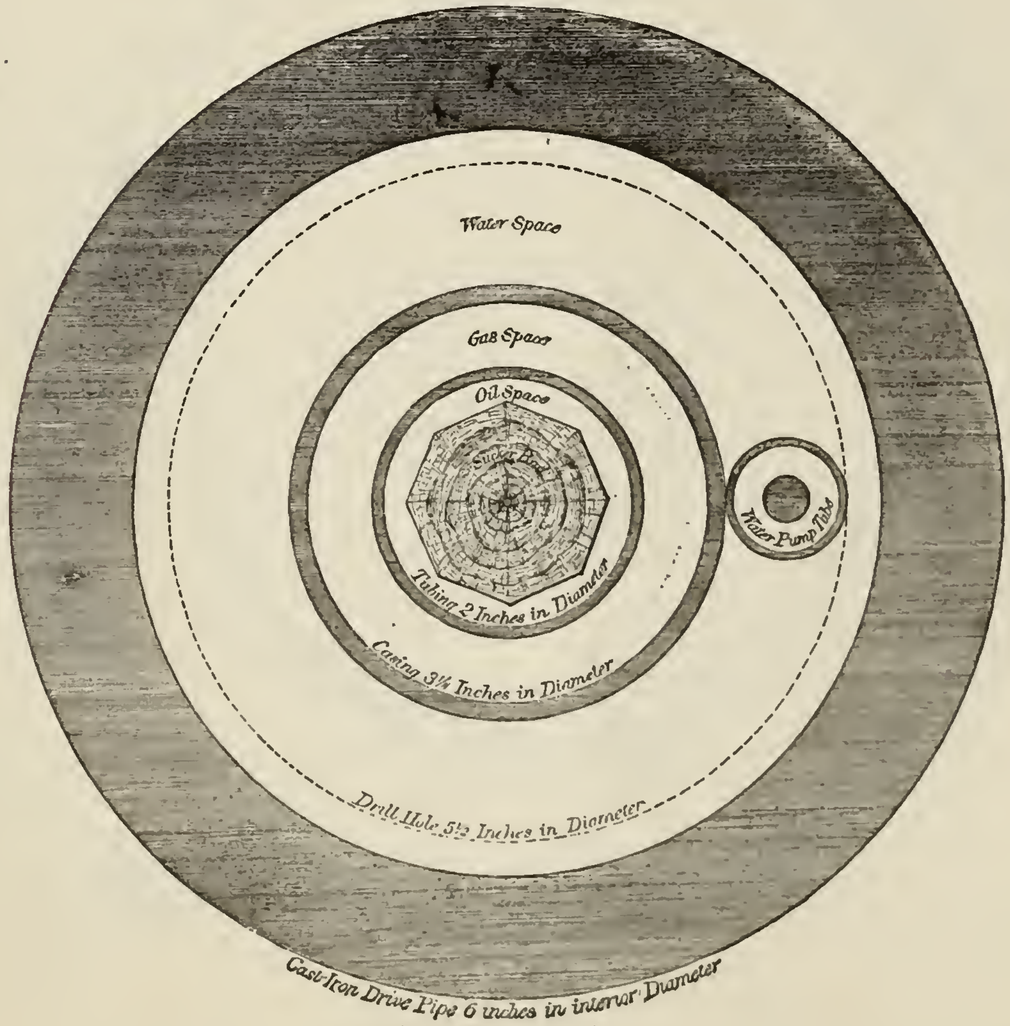


[FIG. 31—page 85.]
Torpedo before explosion.



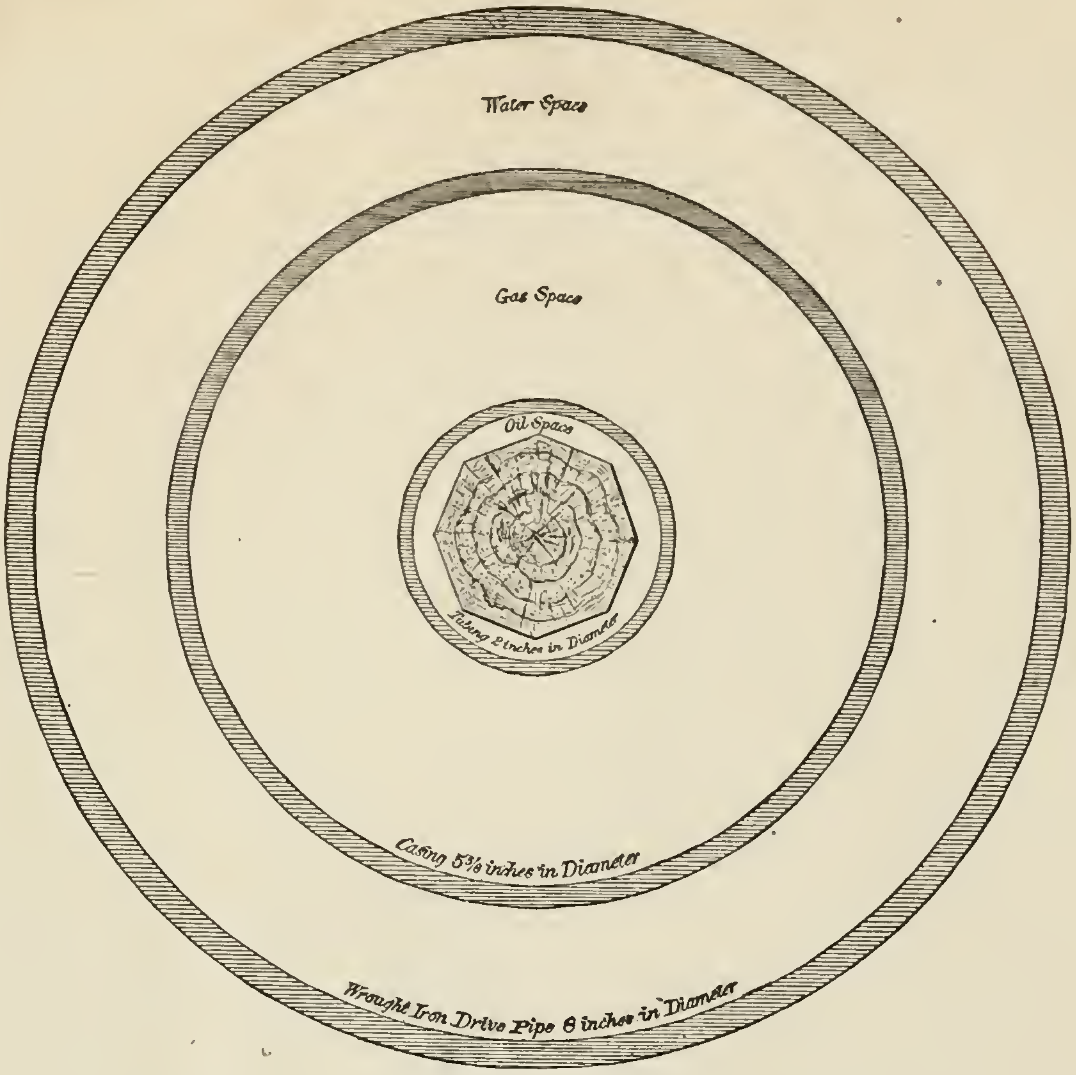
[FIG. 32—page 87.]

Cross-section of pumping well, 1861—wooden conductor.

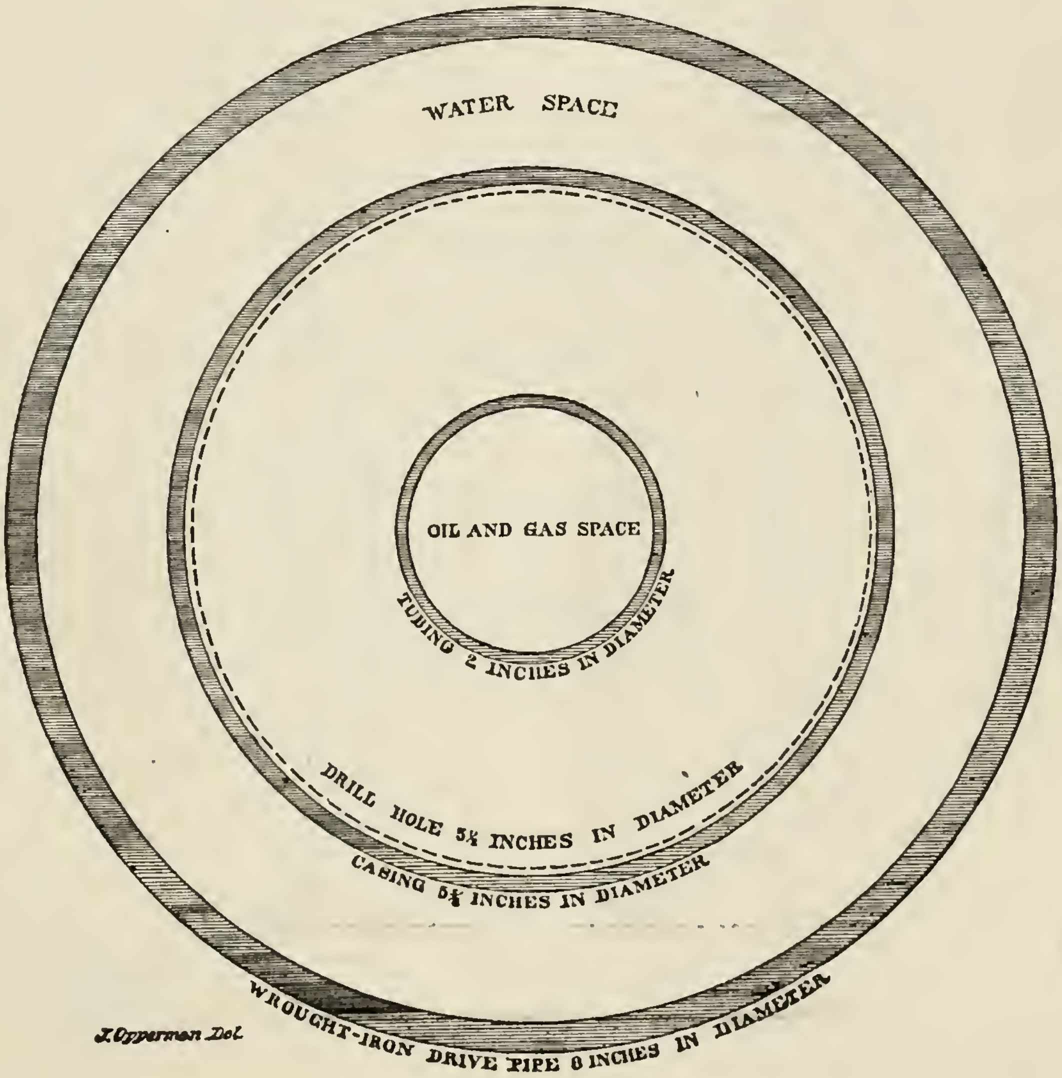


[FIG. 33—page 87.]

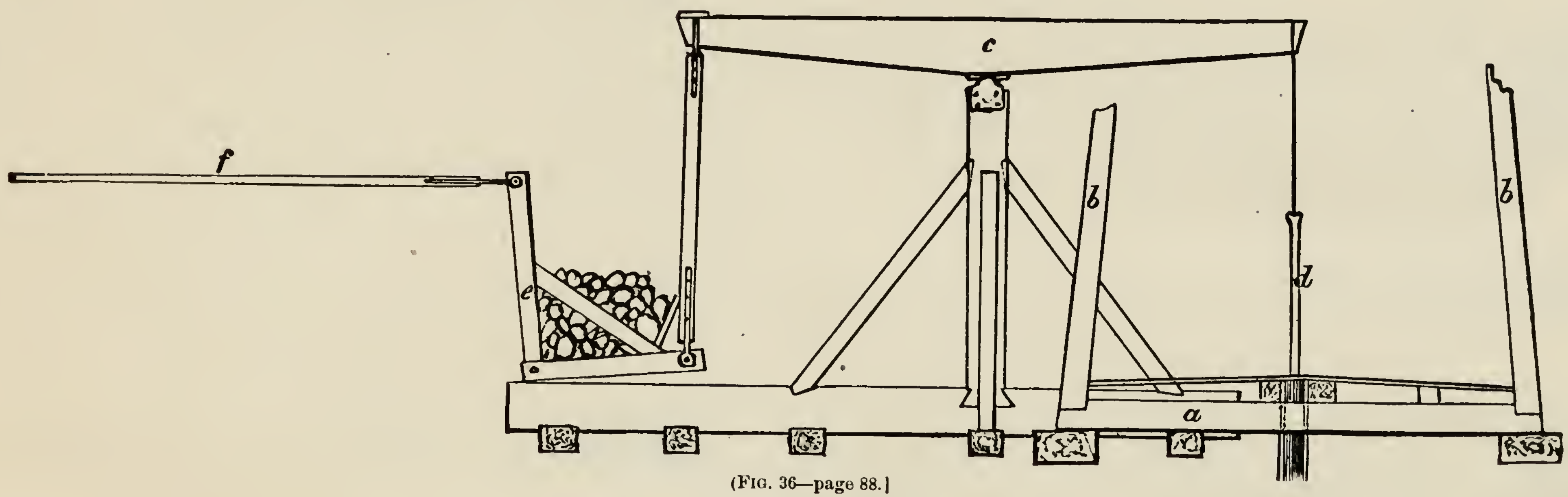
Cross-section of pumping well, 1868—cast-iron drive-pipe.



[FIG. 34—page 87.]
Cross-section of pumping well, wrought-iron drive-pipe, 1878.

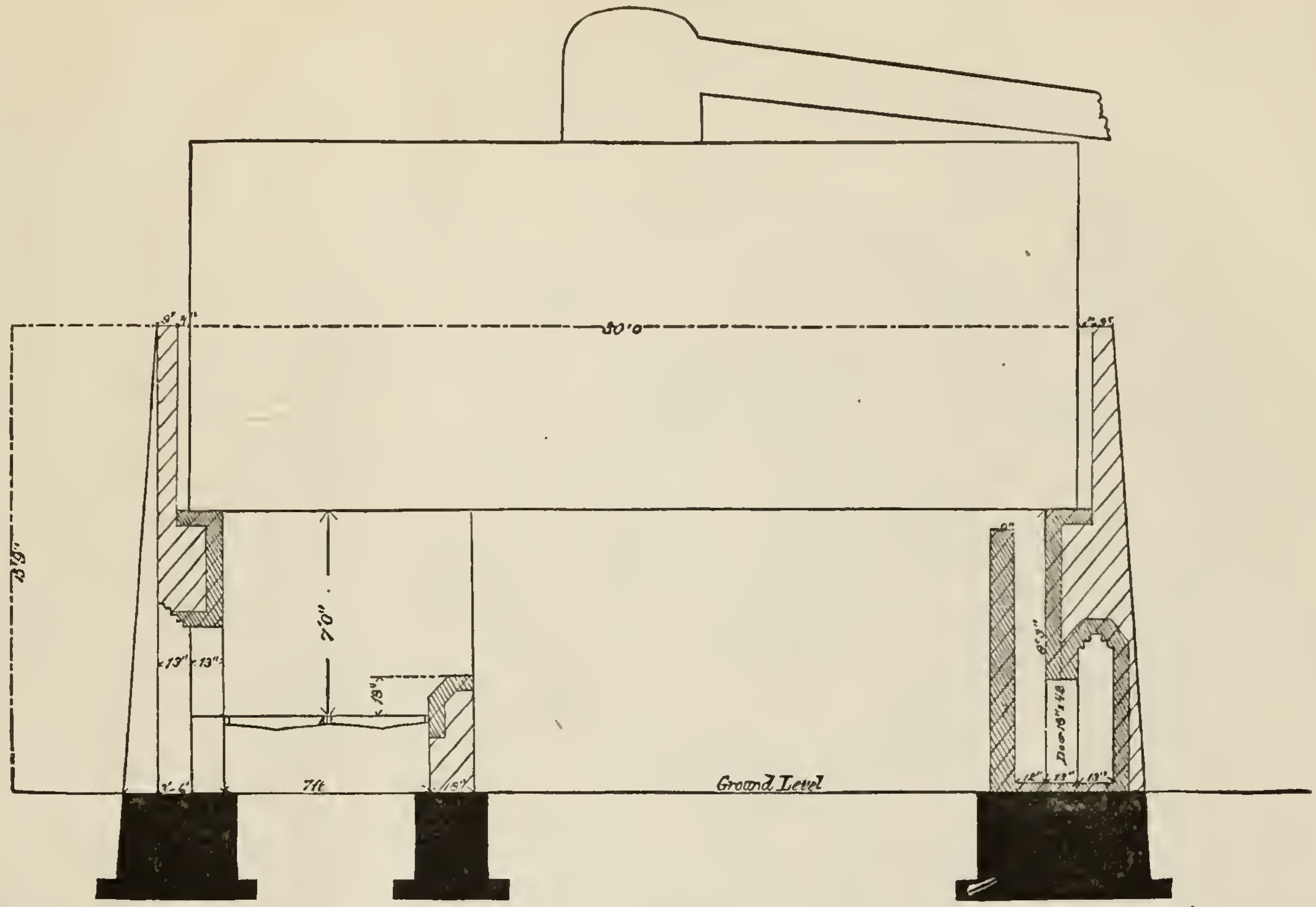


[FIG. 35—page 87.]
Cross-section of flowing well, 1880.

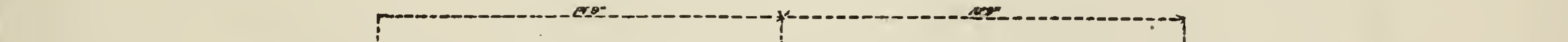


[FIG. 36—page 88.]

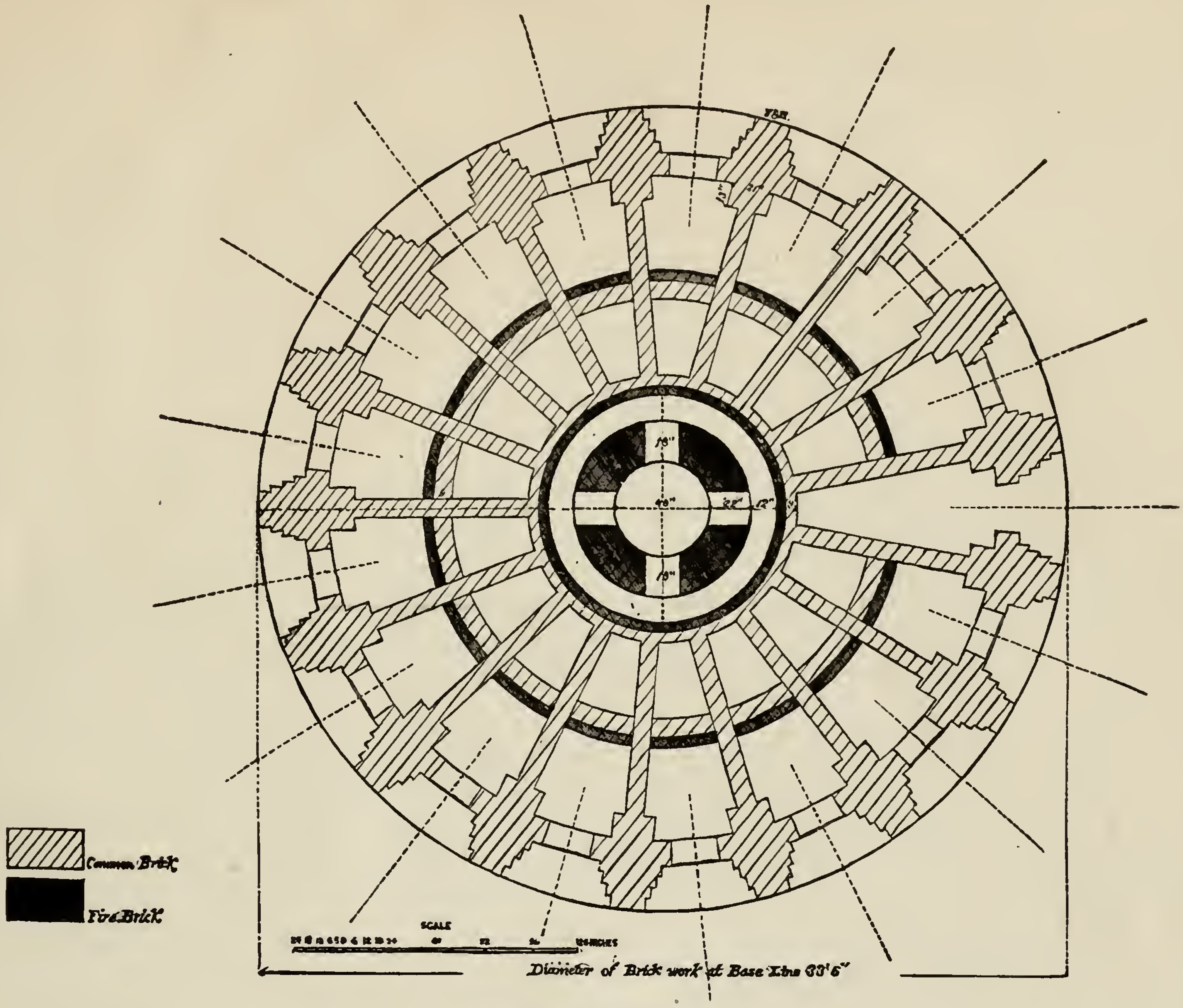
Sucker-rod movement.



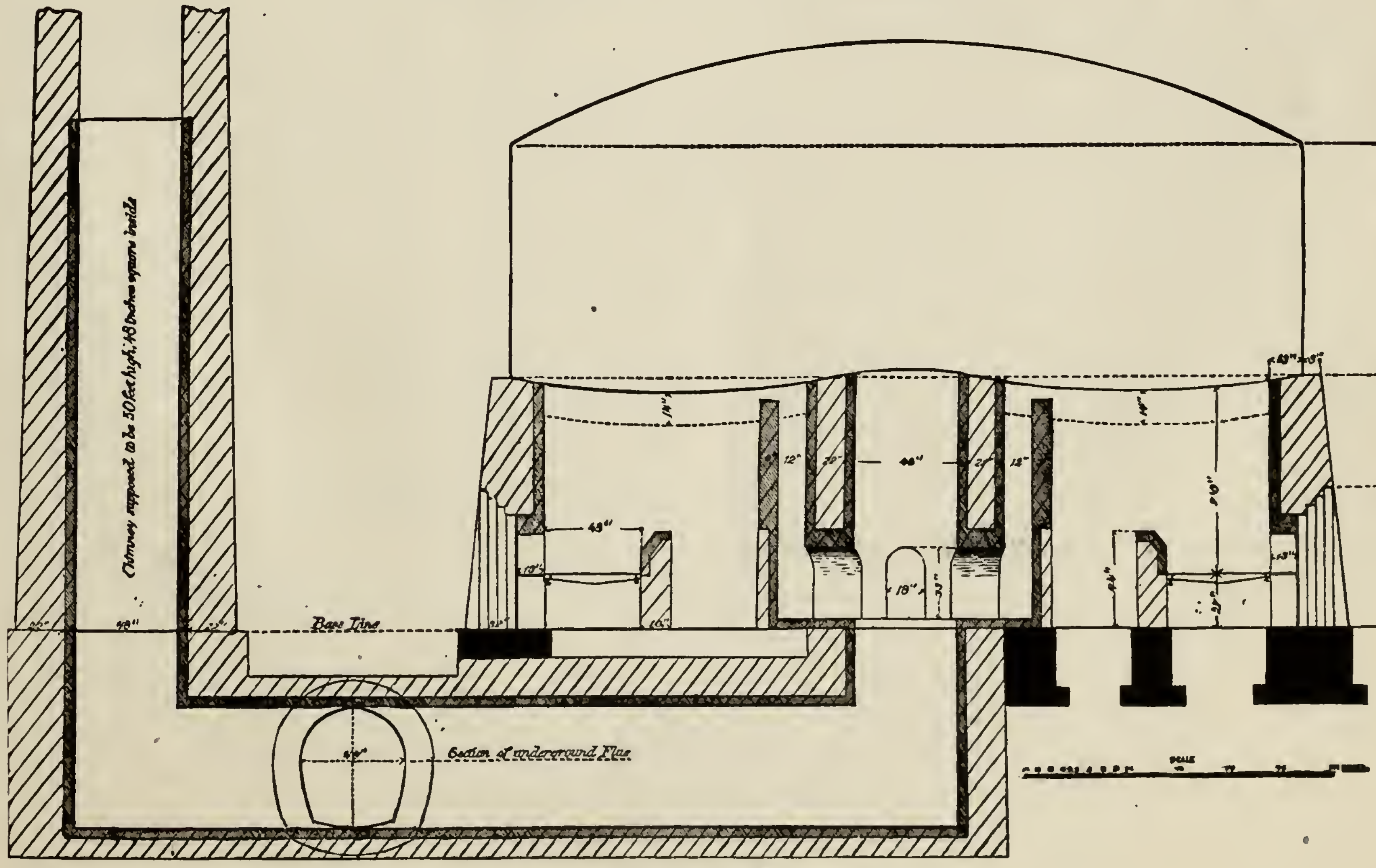
[Fig. 37—page 162.]
Lateral vertical section of cylindrical still.



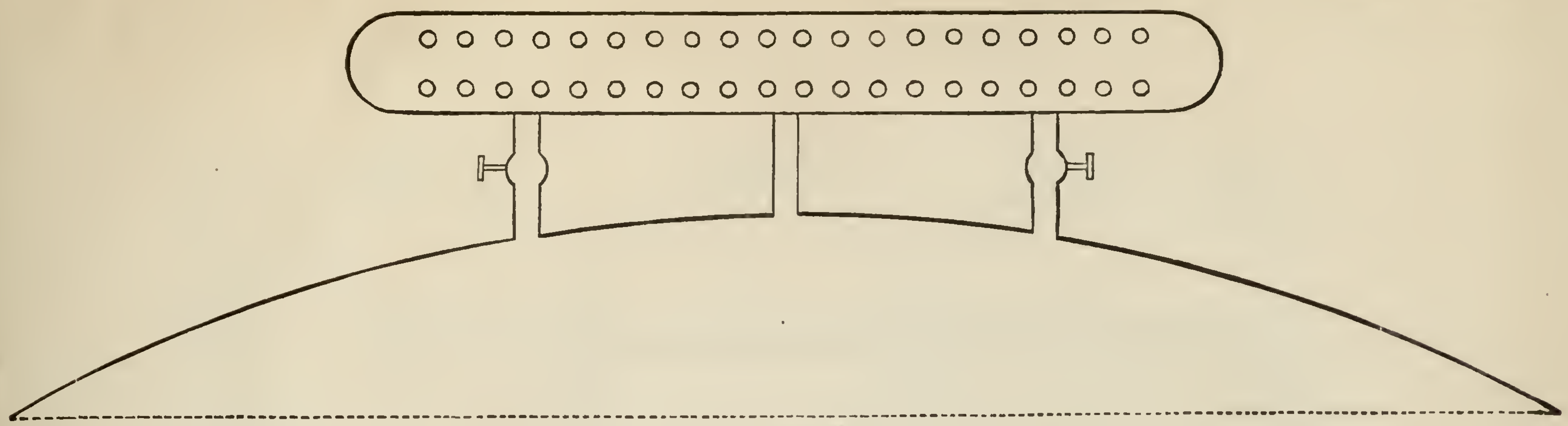
[Fig. 38—page 162.]
Transverse vertical section of cylindrical still.



[FIG. 39—page 162.]
Horizontal section of cheese-box-still setting.

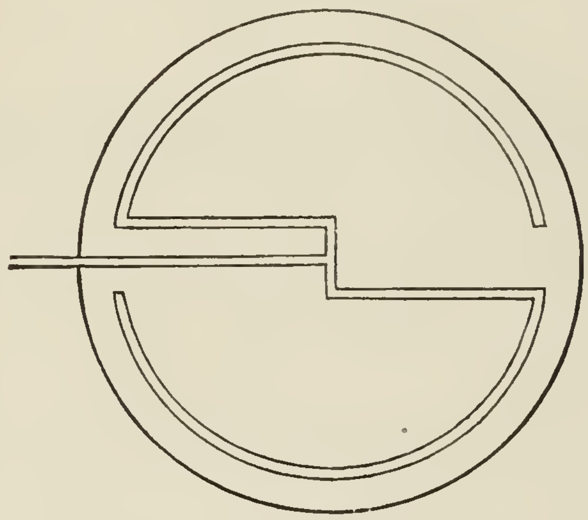


[FIG. 40—page 162.]
Vertical section of cheese-box-still setting.



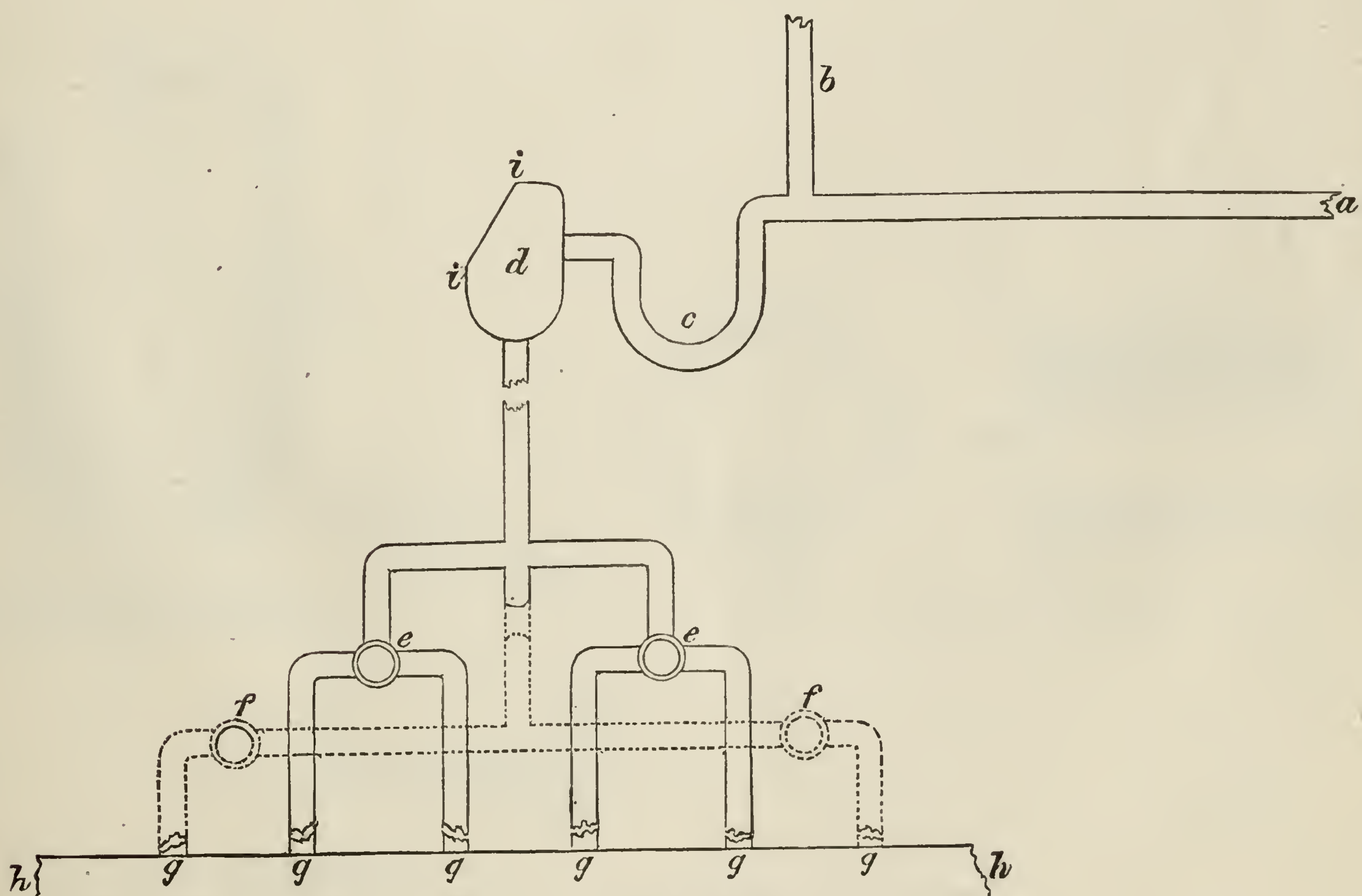
[FIG. 41—page 162.]

Section of condensing drum.



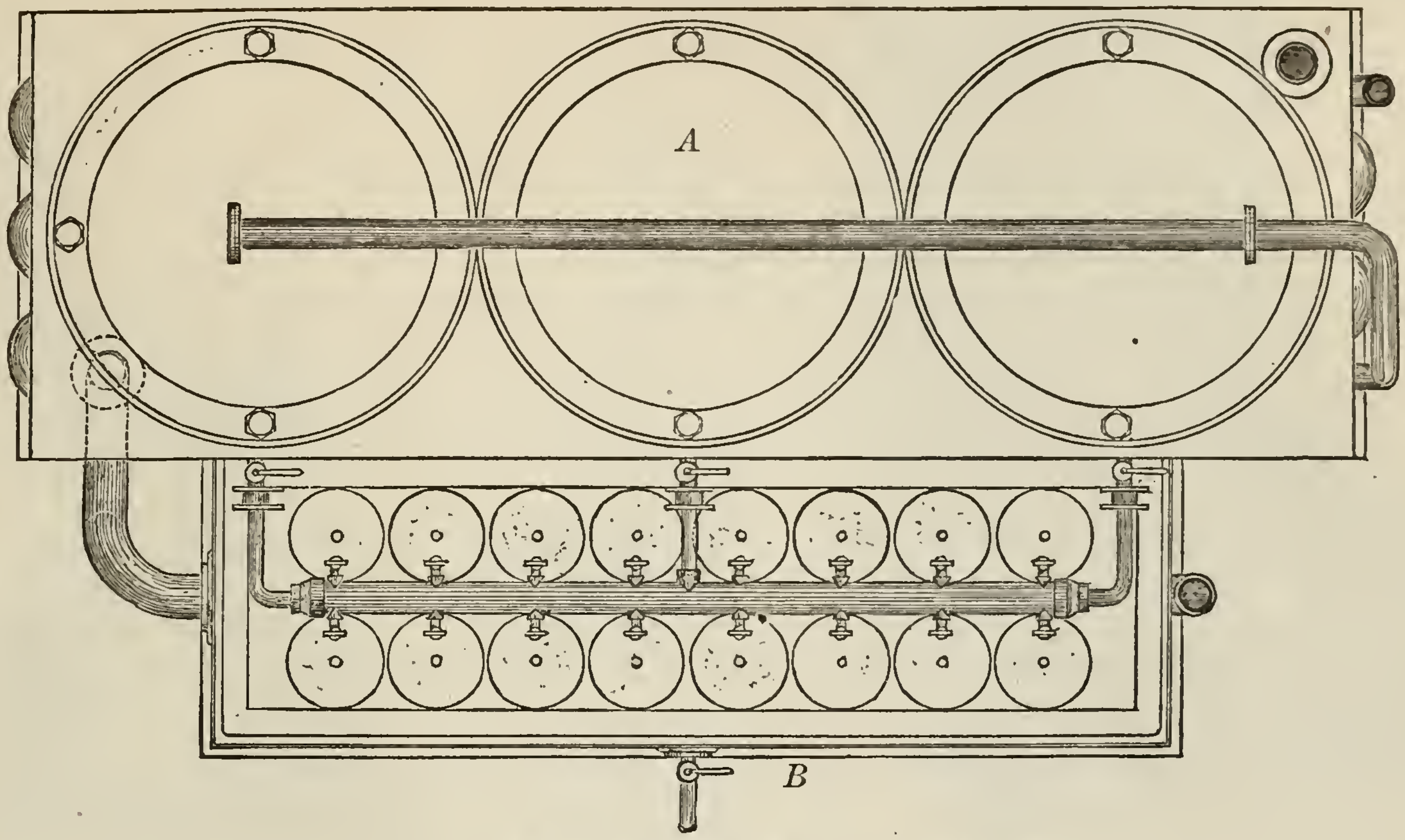
[FIG. 42—page 162.]

Section of steam-pipe for still head.

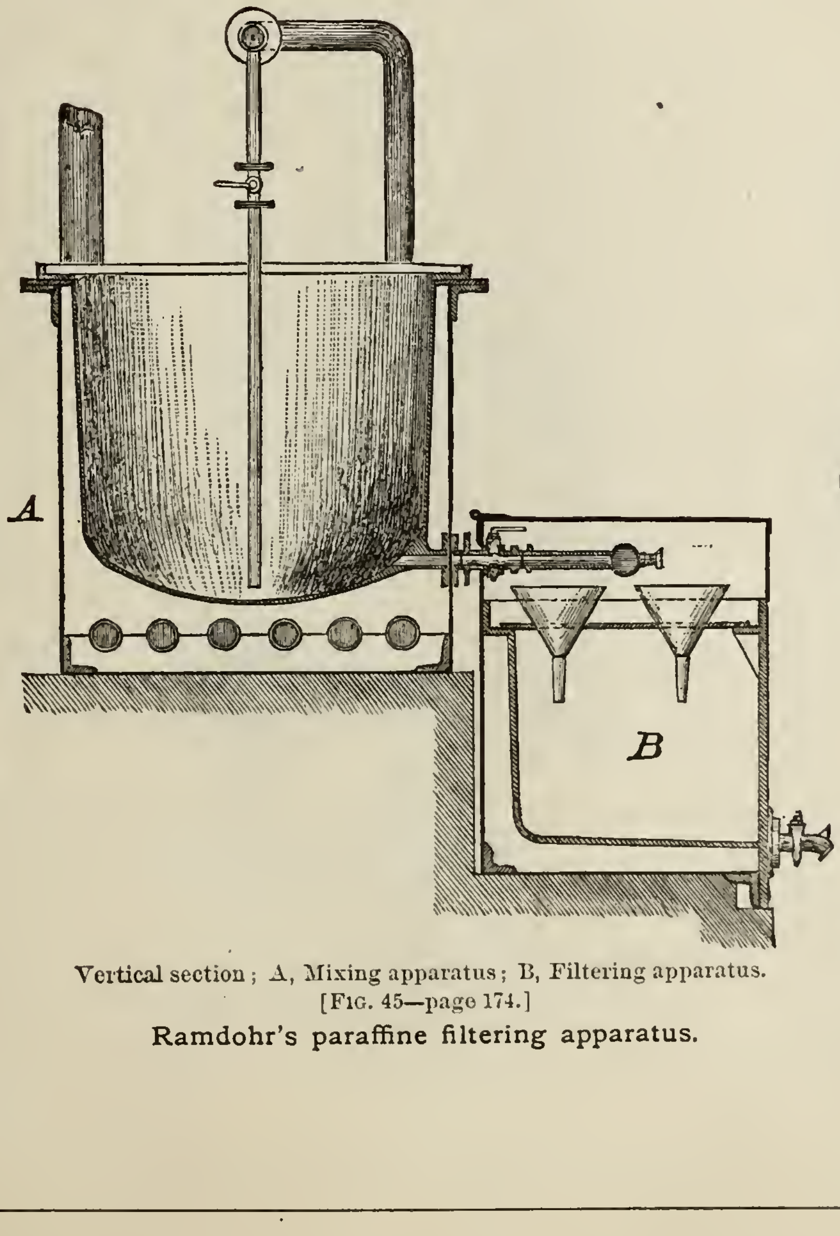


[FIG. 43—page 163.]

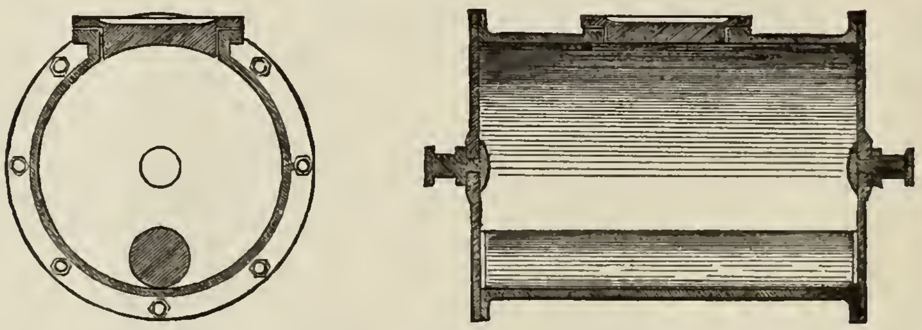
Diagram showing arrangement for distributing distillates.



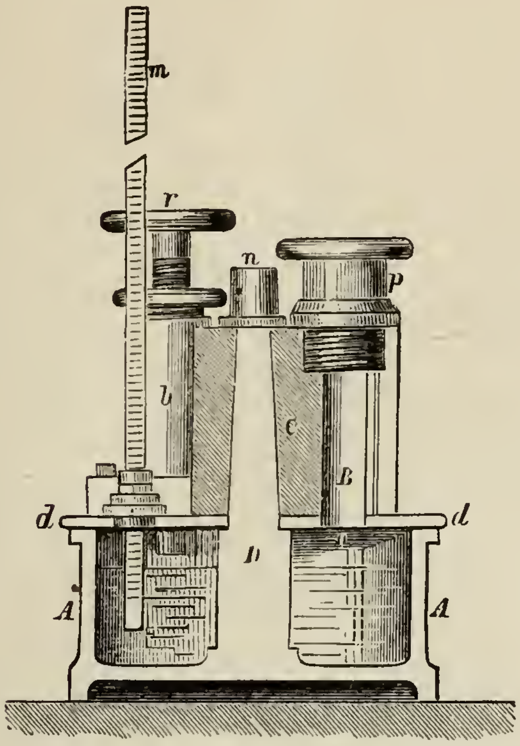
Horizontal section; A, Mixing apparatus; B, Filtering apparatus.
[Fig. 44—page 174.]
Ramdohr's paraffine filtering apparatus.



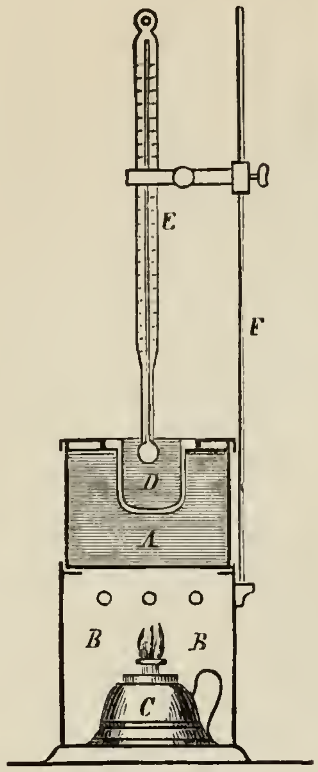
Vertical section; A, Mixing apparatus; B, Filtering apparatus.
[Fig. 45—page 174.]
Ramdohr's paraffine filtering apparatus.



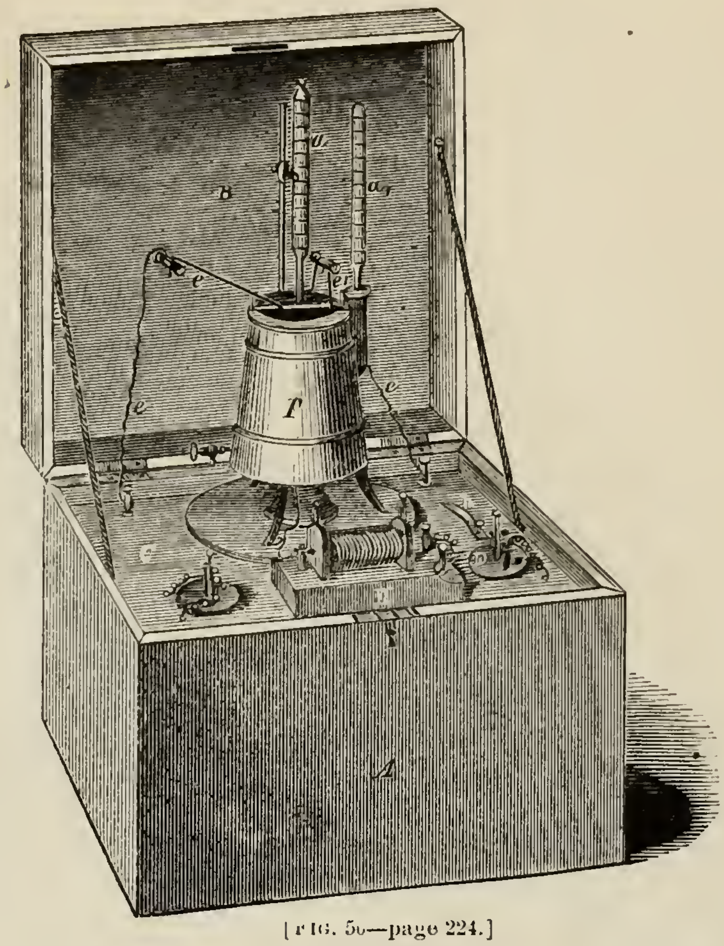
[Figs. 46 and 47—page 175.]
Ramdohr's charcoal pulverizing drum or cylinder.



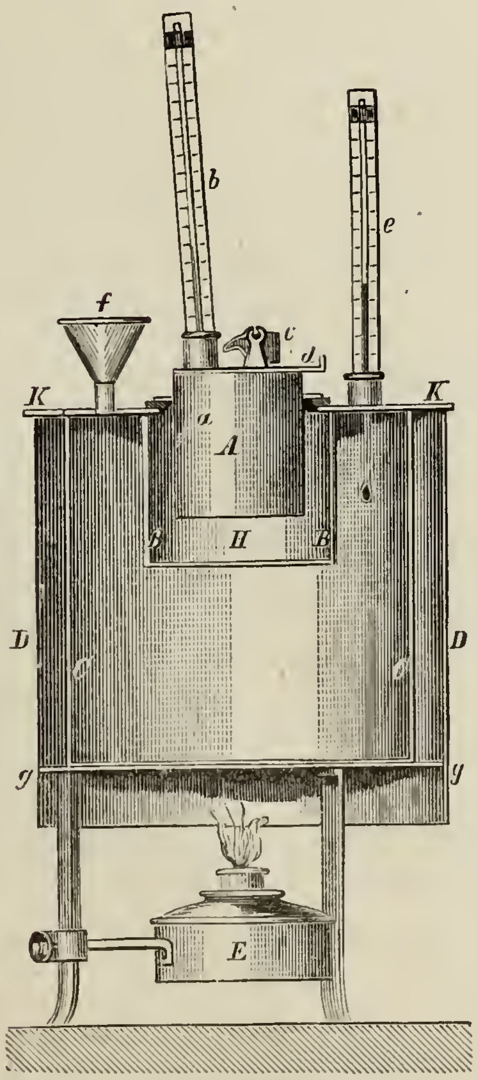
[Fig. 48—page 223.]
Salleron-Urbain tester.



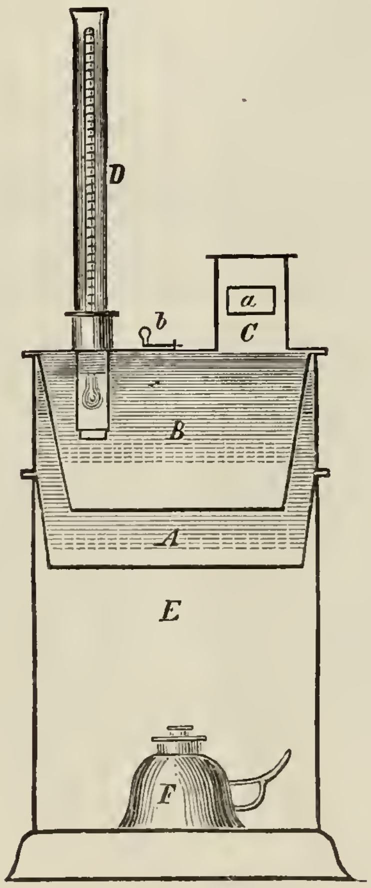
[Fig. 49—page 224.]
Tagliabue's open tester.



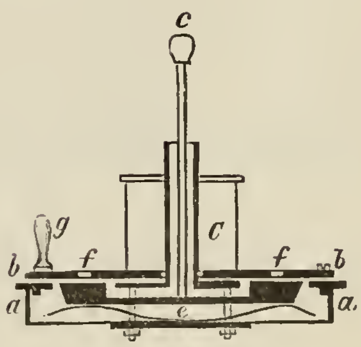
[Fig. 50—page 224.]
Saybolt's tester.



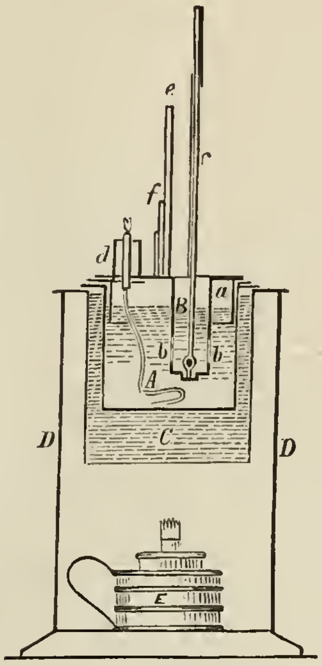
[Fig. 51—page 224.]
Abel's tester.



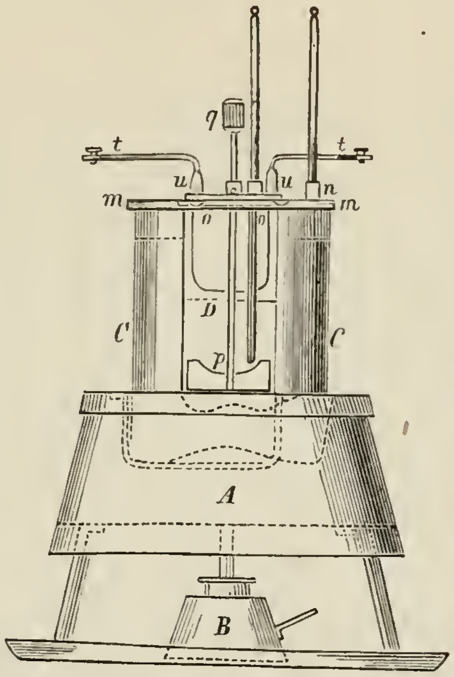
[Fig. 52—page 224.]
Tagliabue's closed tester.



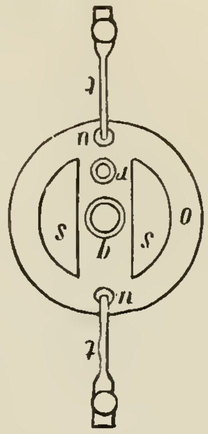
[Fig. 53—page 224.]
Tagliabue's closed tester.



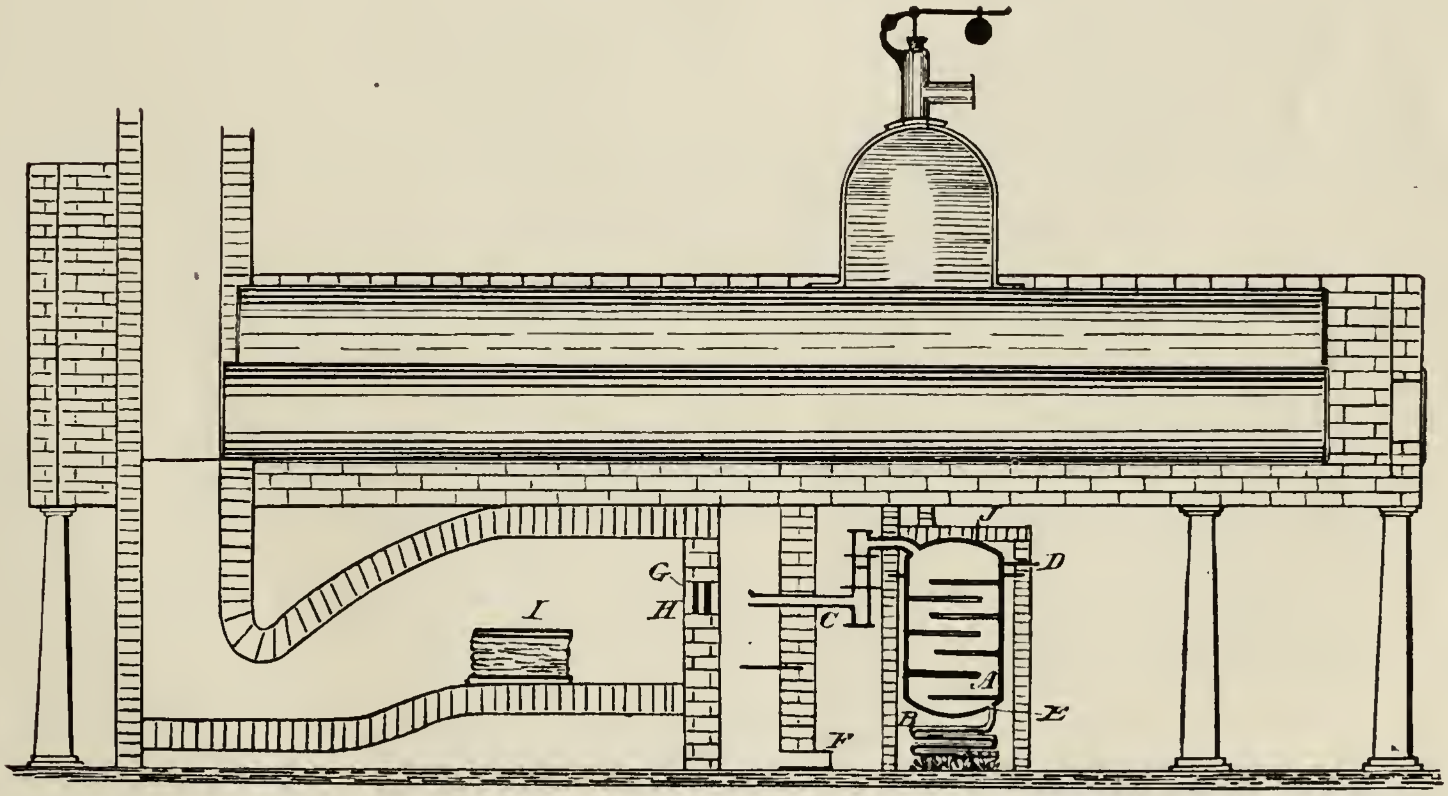
[FIG. 54—page 224.]
Parrish's naphtometer.



[FIG. 55—page 225.]
Engler's tester.



[FIG. 56—page 225.]
Engler's tester.



[FIG. 57—page 250.]
Vertical section of Eames' petroleum furnace.

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1866	*Lartet, Louis	Dead Sea asphalt	B. S. G. F., xxiii, 758.
1866	*Lartet, Louis	Sur les gites bitumineux de la Judée et de la Coele-Syrie, et sur la mode d'arivée de l'asphalte au milieu des eaux de la Mer Morte.	B. S. G. F., xxiv, 12.
1866	Lesley, J. P	On the geological position of petroleum or oil wells	P. A. P. S., x, 189; A. J. S. (2), xli, 130.
1866	*Lesley, J. P	Records of oil borings	P. A. P. S., x, 227, 266.
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1866	Salleron et Urbain	Nouvelle méthode d'essai des huiles minérales	C. R., lxii, 43; Les Mondes, 1866, p. 127; M. Sci., 1866, p. 104; B. S. C. P., 1866, p. 477; Z. A. C., 1866, p. 247; L'A. S. et I., 1866, p. 172; P. M. (3), xxxi, 143; Dingler, clxxxi, 397; D. Ind. Z., 1866, p. 164; W. B., 1866, p. 671.
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1867	Ansted, D. T	On intermittent discharges of petroleum and large deposits of bitumen in the valley of Pescara, Italy.	P. B. A. A. S., 1867, p. 50.
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1867	Coffey, A	System of fractional distillation of mineral oils	Eng., 1866, p. 394; Le Tech., xxix, 69; Dingler, clxxxv, 276.
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1867	Hoffmann, B	Der Ozokerit	Bayer. K. u. Gbl., 1867, p. 186; Dingler, clxxxiv, 378; Poly. Cbl., 1867, p. 288; Poly. Nbl., 1867, p. 142; W. B., 1867, p. 736.
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1867	*Oldham, T	Punjab oil	Memorandum on the results of a cursory examination of the Salt Range, etc., reprinted in a supplement to the Gazette of India, Aug. 24, 1867, p. 780.
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